TITLE PAGE

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Microsoft(R) MS-DOS(R)

Version 3.3

Programmer's Reference

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Chapter 1 System Calls

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1.1 Introduction

The routines that MS-DOS uses to manage system operation and resources can be called by any application program. Using these system calls makes it easier to write machine-independent programs and increases the likelihood that a program will be compatible with future versions of MS-DOS. MS-DOS system calls fall into several categories:

- Standard character device I/O
- Memory management
- Process management
- File and directory management
- Microsoft Network calls
- National Language Support calls
- Miscellaneous system functions

Applications invoke MS-DOS services by using software interrupts. The current range of interrupts used for MS-DOS is 20H-27H; 28H-40H are reserved. Interrupt 21H is the function request service; it provides access to a wide variety of MS-DOS services. In some cases, the full AX register is used to specify the requested function. Each interrupt or function request uses values in various registers to receive or return function-specific information.

1.1.1 System Calls That Have Been Superseded

Many system calls introduced in versions of MS-DOS earlier than 2.0 have been superseded by function requests that are more efficient and easier to use. Although MS-DOS still includes these old system calls, they should not be used unless it is imperative that a program maintain backward-compatibility with versions of MS-DOS before 2.0.

A table of the pre-2.0 system calls and a description of the File Control Block (required by some of the old calls) appears in Section 1.8, "Old System Calls."

The first part of this chapter explains how DOS manages its resources--such as memory, files, and processes--and briefly describes the purpose of most of the system calls. The remainder of the chapter describes each interrupt and function request in detail.

The system-call descriptions are in numeric order, interrupts followed by function requests. These descriptions include further detail on how MS-DOS manages its resources.

Chapter 2 of this manual describes how to write an MS-DOS device driver. Chapters 3, 4, and 5 contain more detailed information about MS-DOS, including how it manages disk space, the control blocks it uses, and how it loads and executes relocatable programs (files with an extension of .exe). Chapter 6 describes the Intel object module format. Chapter 7 gives some programming hints.

1.2 Standard Character Device I/O

The standard character function requests handle all input and output to and from character devices such as consoles, printers, and serial ports. If a program uses these function requests, its input and output can be redirected.

Table 1.1 lists the MS-DOS function requests for managing standard character input and output.

Table 1.1
Standard Character I/O Function Requests

Code	Request	Description
Code	Request	Description
01H	Read Keyboard and Echo	Gets a character from standard input and echoes it to standard output
02H	Display Character	Sends a character to standard output
03H	Auxiliary Input	Gets a character from standard auxiliary
04H	Auxiliary Output	Sends a character to standard auxiliary
05H	Print Character	Sends a character to the standard printer
06H	Direct Console I/O	Gets a character from standard input or sends a character to standard output
07H	Direct Console	Gets a character from standard input
Code	Request	Description
07H	Direct Console Input	Gets a character from standard input
08H	Read Keyboard	Gets a character from standard input
09H	Display String	Sends a string to standard output
0AH	Buffered Keyboard Input	Gets a string from standard input
0BH	Check Keyboard Status	Reports on the status of the standard input buffer
0CH	Flush Buffer, Read Keyboard	Empties the standard input buffer and calls one of the other standard character I/O function requests

Although several of these standard character I/O function requests seem to do the same thing, they are distinguished by whether they check for control characters or echo characters from standard input to standard output. The detailed descriptions later in this chapter point out the differences.

1.3 Memory Management

MS-DOS keeps track of which areas of memory are allocated by writing a

memory control block at the beginning of each. This control block specifies the size of the memory area; the name of the process, if any, that owns the memory area; and a pointer to the next area of memory. If the memory area is not owned, it is available.

Table 1.2 lists the MS-DOS function requests for managing memory.

Table 1.2
Memory-Management Function Requests

Code	Request	Description
Code	Request	Description
48H	Allocate Memory	Requests a block of memory
49H	Free Allocated Memory	Frees a block of memory previously allocated with 48H
4AH	Set Block	Changes the size of an allocated memory block

When a process requests additional memory with Function 48H (Allocate Memory), MS-DOS searches for a block of available memory large enough to satisfy the request. If it finds such a block of memory, it changes the memory control block to show the owning process. If the block of memory is larger than the requested amount, MS-DOS changes the size field of the memory control block to the requested amount, writes a new memory control block at the beginning of the unneeded portion showing that it is available, and updates the pointers to add this memory to the chain of memory control blocks. MS-DOS then returns the segment address of the first byte of the allocated memory to the requesting process.

When a process releases an allocated block of memory with Function 49H (Free Allocated Memory), MS-DOS changes the memory control block to show that it is available (not owned by any process).

When a process uses Function 4AH (Set Block) to shrink an allocated block of memory, MS-DOS builds a memory control block for the memory being released and adds it to the chain of memory control blocks. When a process tries to use Function 4AH (Set Block) to expand an allocated block of memory, MS-DOS treats it as a request for additional memory rather than returning the segment address of the additional memory to the requesting process. However, MS-DOS simply chains the additional memory to the existing memory block.

If MS-DOS can't find a block of available memory large enough to satisfy a request for additional memory made with either Function 48H (Allocate Memory) or Function 4AH (Set Block), MS-DOS returns an error code to the requesting process.

When a program receives control, it should call Function 4AH (Set Block) to shrink its initial memory-allocation block (the block that begins with its Program Segment Prefix) to the minimum it requires. This frees unneeded memory and makes the best application design for portability to future multitasking environments.

When a program exits, MS-DOS automatically frees its initial memory-allocation block before returning control to the calling program (command.com is usually the calling program for application programs). The DOS frees any memory owned by the exiting process.

Any program that changes memory that is not allocated to it will most likely destroy at least one memory-management control block. This causes a memory-allocation error the next time MS-DOS tries to use the chain of memory control blocks; the only cure is to restart the system.

1.4 Process Management

MS-DOS uses several function requests to load, execute, and terminate programs. Application programs can use these same function requests to manage other programs.

Table 1.3 lists the MS-DOS function requests for managing processes.

Table 1.3
Process-Management Function Requests

Code	Request	Description
31H	Keep Process	Terminates a process and returns control to the invoking process, but keeps the terminated process in memory
4BH	Load and Execute Program	Loads and executes a program
4B03H	Load Overlay	Loads a program overlay without executing it
Code	Request	Description
4CH	End Process	Returns control to the invoking process
4DH	Get Return Code of Child Process	Returns a code passed by an exiting child process
62H	Get PSP	Returns the segment address of the current process's Program Segment Prefix

1.4.1 Loading and Executing a Program

When a program uses Function 4BH (Load and Execute Program) to load and execute another program, MS-DOS allocates memory, writes a Program Segment Prefix (PSP) for the new program at offset 0 of the allocated memory, loads the new program, and passes control to it. When the invoked program exits, control returns to the calling program.

Command.com uses Function 4BH to load and execute command files. Application programs have the same degree of control over process management as does command.com.

In addition to these common features, there are some differences in the way MS-DOS loads .com and .exe files.

Loading a .com Program

When command.com loads and executes a .com program, it allocates all available memory to the application and sets the stack pointer 100H bytes from the end of available memory. A .com program should set up its own stack before shrinking its initial memory-allocation block with Function 4AH (Set Block) because the default stack is in the memory to be released.

If a newly loaded program is allocated all of memory--as a .com program is--or requests all of available memory by using Function 48H (Allocate Memory), MS-DOS allocates to it the memory occupied by the transient part of command.com. If the program changes this memory, MS-DOS must reload the transient portion of command.com before it can continue. If a program exits (via Function 31H, Keep Process) without releasing enough memory, the system halts and must be reset. To minimize this possibility, a .com program should use Function 4AH (Set Block) to shrink its initial allocation block before doing anything else, and before exiting, all programs must release all memory they allocate by using Function 48H (Allocate Memory).

Loading an .exe Program

When command.com loads and executes an .exe program, it allocates the size of the program's memory image plus either the value in the MAX_ALLOC field (offset 0CH) of the file header (if that much memory is available) or the value in the MIN_ALLOC field (offset 0AH). The linker sets these fields. Before passing control to the .exe file, MS-DOS uses the relocation information in the file header to calculate the correct relocation addresses.

For a more detailed description of how MS-DOS loads .com and .exe files, see Chapter 3, "MS-DOS Technical Information," and Chapter 4, "MS-DOS Control Blocks and Work Areas."

Executing a Program from Within Another Program

Since command.com builds pathnames, searches directory paths for executable files, and relocates .exe files, the simplest way to load and execute a program is to load and execute an additional copy of command.com, passing it a command line that includes the /C switch, which invokes the .com or .exe file. The description of Function 4B00H (Load and Execute Program) describes how to do this.

1.4.2 Loading an Overlay

When a program uses Function 4B03H (Load Overlay) to load an overlay, it must pass MS-DOS the segment address at which the overlay is to be loaded. The program must call the overlay, which then returns directly to the calling program. The calling program is in complete control: MS-DOS does not write a PSP for the overlay or intervene in any other way.

MS-DOS does not check to see if the calling program owns the memory where the overlay is to be loaded. If the calling program does not own the memory, loading the overlay will most likely destroy a memory-control block, causing an eventual memory-allocation error.

Therefore, a program that loads an overlay must either allow room for the overlay when it calls Function 4AH (Set Block) to shrink its initial memory-allocation block, or shrink its initial memory-allocation block to the minimum and then use Function 48H (Allocate Memory) to allocate memory for the overlay.

1.5 File and Directory Management

The MS-DOS hierarchical (multilevel) file system is similar to that of the XENIX operating system. For a description of the multilevel directory system and how to use it, see the MS-DOS User's Reference.

1.5.1 Handles

To create or open a file, a program passes MS-DOS a pathname and the attribute to be assigned to the file. MS-DOS returns a 16-bit number, called a handle. For most subsequent actions, MS-DOS requires only this handle to identify the file.

A handle can refer to either a file or a device. MS-DOS predefines five standard handles. These handles are always open, so you needn't open them before you use them. Table 1.4 lists these predefined handles.

Table 1.4
Predefined Device Handles

Handle	Standard device	Comment
0	Input	Can be redirected from command line
1	Output	Can be redirected from command line
2	Error	
3	Auxiliary	
4	Printer	

When MS-DOS creates or opens a file, it assigns the first available handle. Since a program can have 20 open handles, including the five predefined handles, it typically can open 15 extra files. By using Function 46H (Force Duplicate File Handle), MS-DOS can temporarily force any of the five predefined handles to refer to an alternate file or device. For more information about Function 46H, see its description later in this chapter.

1.5.2 File-Related Function Requests

MS-DOS treats a file as a string of bytes; it assumes no record structure or access technique. An application program imposes whatever record structure it needs on this string of bytes. Reading from or writing to a file requires only pointing to the data buffer and specifying the number of bytes to read or write.

Table 1.5 lists the MS-DOS function requests for managing files.

Table 1.5
File-Related Function Requests

Code	Request	Description
3CH	Create Handle	Creates a file
3DH	Open Handle	Opens a file
3EH	Close Handle	Closes a file
3FH	Read Handle	Reads from a file

40H	Write Handle	Writes to a file
42H	Move File Pointer	Sets the read/write pointer in a file
45H	Duplicate File Handle	Creates a new handle that refers to the same file as an existing handle

Code	Request	Description
46H	Force Duplicate File Handle	Makes an existing handle refer to the same file as another existing handle
5AH	Create Temporary File	Creates a file with a unique name
5BH	Create New File	Attempts to create a file, but fails if a file with the same name exists
67H	Set Handle Count	Increases or decreases the number of files a program can have open at one time
68H	Commit File	Flushes buffered data for a file without closing it to ensure the disk image of that file is current

File Sharing

Version 3.1 of MS-DOS introduces file sharing, which lets more than one process share access to a file. File sharing operates only after the share command has been executed to load file-sharing support. That is, you must use the share command to take advantage of file sharing.

Table 1.6 lists the MS-DOS function requests for sharing files; if file sharing is not in effect, these function requests cannot be used. Function 3DH (Open Handle) can operate in several modes. Here it is referred to in the file-sharing modes, which require file sharing to be in effect. (Compatibility mode is usable without file sharing in effect.)

Table 1.6
File-Sharing Function Requests

Code	Request	Description
3DH	Open Handle	Opens a file by using one of the file-sharing modes

Code	Request	Description
440BH	IOCtl Retry	(before Interrupt 24 is issued) Specifies how many times to retry an I/O operation that fails due to a file-sharing violation
5C00H	Lock	Locks a region of a file
5C01H	Unlock	Unlocks a region of a file

1.5.3 Device-Related Function Requests

I/O Control for devices is implemented with Function 44H (IOCtl), which includes several subfunctions necessary to perform device-related tasks. Some forms of the IOCtl function request require that the device driver be written to support the IOCtl interface. Table 1.7 lists the MS-DOS function requests for managing devices.

Table 1.7
Device-Related Function Requests

Code	Request	Description
4400H,01H	IOCtl Data	Gets or sets device description
4402H,03H	IOCtl Character	Gets or sets character-device control data
4404H,05H	IOCtl Block	Gets or sets block-device control data
4406H,07H	IOCtl Status	Checks device input or output status
4408H	IOCtl Is Changeable	Checks whether block device contains removable medium
Code	Request	Description
440CH	Generic IOCtl (for handles)	Sets Generic IOCtl for handles and supports code pages for devices
440DH	Generic IOCtl (for devices)	Sets Generic IOCtl for devices
440E,0FH	Get/Set IOCtl Drive Map	Gets or sets logical drive map

Some forms of the IOCtl function request can be used only with Microsoft Networks; these forms are listed in Section 1.6, "Microsoft Networks."

1.5.4 Directory-Related Function Requests

A directory entry is a 32-byte record that includes the file's name, extension, date and time of last change, and size. An entry in a subdirectory is identical to an entry in the root directory. Directory entries are described in detail in Chapter 3, "MS-DOS Technical Information."

The root directory on a disk has room for a fixed number of entries: 64 on a standard single-sided disk, 112 on a standard double-sided disk. For hard disks, the number of directories depends on the DOS partition size. A subdirectory is simply a file with a unique attribute; there can be as many subdirectories on a disk as space allows. The depth of a directory structure, therefore, is limited only by the amount of storage on a disk and the maximum pathname length of 64 characters. Pre-2.0 disks appear to have only a root directory that contains files but no subdirectories.

Table 1.8 lists the MS-DOS function requests for managing directories.

Table 1.8
Directory-Related Function Requests

Code	Request	Description
39H	Create Directory	Creates a subdirectory
Code	Request	Description
39H	Create Directory	Creates a subdirectory
3AH	Remove Directory	Deletes a subdirectory
3BH	Change Current Directory	Changes the current directory
41H	Delete Directory Entry (Unlink)	Deletes a file
43H	Get/Set File Attributes (Chmod)	Retrieves or changes the attributes of a file
47H	Get Current Directory	Returns current directory for a given drive
4EH	Find First File	Searches a directory for the first entry that matches a filename
4FH	Find Next File	Searches a directory for the next entry that matches a
Code	Request	Description
		next entry that matches a filename
56H	Change Directory Entry	Renames a file
57H	Get/Set Date/Time of File	Changes the time and date of last change in a directory entry

1.5.5 File Attributes

Table 1.9 describes the file attributes and how they are represented in the attribute byte of the directory entry (offset 0BH). The attributes can be inspected or changed with Function 43H (Get/Set File Attributes [Chmod]).

Table 1.9
File Attributes

Code	Description
00H	Normal; can be read or written without restriction
01H	Read-only; cannot be opened for write; a file with the same name cannot be created
02H	Hidden; not found by directory search
04H	System; not found by directory search
08H	VolumeID; only one file can have this attribute; it must be in the root directory

10H Subdirectory

20H Archive; set whenever the file is changed, or cleared by the Backup command

The VolumeID (08H) and Subdirectory (10H) attributes cannot be changed with Function 43H (Get/Set File Attributes [Chmod]).

1.6 Microsoft Networks

Microsoft Networks consists of a server and one or more workstations. MS-DOS maintains an assign list that keeps track of which workstation drives and devices have been redirected to the server. For a description of operation and use of the network, see the Microsoft Networks 1.0 Manager's Guide and Microsoft Networks 1.0 User's Guide.

Table 1.10 lists the MS-DOS function requests for managing a Microsoft Networks workstation.

Table 1.10
Microsoft Networks Function Requests

Code	Request	Description
4409H	IOCtl Is Redirected Block	Checks whether a drive letter refers to a local or redirected drive
440AH	IOCtl Is Redirected Handle	Checks whether a device name refers to a local or redirected device
5E00H	Get Machine Name	Gets the network name of the workstation
5E02H	Printer Setup	Defines a string of control characters to be added at the beginning of each file that is sent to a network printer
5F02H	Get Assign-List Entry	Gets an entry from the assign list, which shows the workstation drive letter or device name and the net name of the directory or device on the server to which the entry is reassigned
Code	Request	Description
5F03H	Make Assign-List Entry	Redirects a workstation drive or device to a server directory or device
5F04H	Cancel Assign-List Entry	Cancels the redirection of a workstation drive or device to a server directory or device

1.7 National Language Support

National language support for this version of MS-DOS includes these major features:

- Country-dependent information
- Support for national keyboard layouts
- Programming interfaces for national language support
- Utility commands

Country-dependent information is available on a per-country basis and includes the following:

- Time, date, and currency
- Lowercase-to-uppercase character-conversion tables
- Collating sequence for character sorting
- Valid single-byte characters used in filenames

Keyboard support for different keyboard layouts is provided and selectable.

Table 1.11 lists the MS-DOS national-language-support system calls that allow applications to use the country-dependent information just described.

Table 1.11
National Language-Support Function Requests

Code	Request	Description
65H	Get Extended Country Information	Returns standard country information, pointer to uppercase table, pointer to filename uppercasing table, or pointer to collating table
66H	Get/Set Global Code Page	Gets or sets the code page used by the kernel and all devices.

1.8 Miscellaneous System-Management Functions

The remaining system calls manage other system functions and resources such as drives, addresses, and the clock. Table 1.12 lists the MS-DOS function requests for managing miscellaneous system resources and operation.

Table 1.12
Miscellaneous System-Management Function Requests

Code	Request	Description
0DH	Reset Disk	Empties all file buffers
0EH	Select Disk	Sets the default drive
19H	Get Current Disk	Returns the default drive

	1AH	Set Disk Transfer Address	Establishes the disk I/O buffer
	1BH	Get Default Drive Request	Returns disk-format data
	Code		Description
#	1BH	Get Default Drive Data	Returns disk-format data
	1CH	Get Drive Data	Returns disk-format data
	25H	Set Interrupt Vector	Sets interrupt-handler address
	29H	Parse File Name	Checks string for valid filename
	2AH	Get Date	Returns system date
	2BH	Set Date	Sets system date
	2CH	Get Time	Returns system time
	2DH	Set Time	Sets system time
	2EH	Set/Reset Verify Flag	Turns disk verify on or off
	2FH	Get Disk Transfer Request	Returns system-disk-I/O-buffer
	Code		Description
#	2FH	Get Disk Transfer Address	Returns system-disk-I/O-buffer address
	30H	Get MS-DOS Version Number	Returns MS-DOS version number
	33H	CONTROL-C Check	Returns CONTROL-C check status
	35H	Get Interrupt Vector	Returns address of interrupt handler
	36H	Get Disk Free Space	Returns disk-space data
	38H	Get/Set Country Data	Sets current country or retrieves country information
	54H	Get Verify State	Returns status of disk verify

1.9 Old System Calls

Most of the superseded system calls deal with files. Table 1.13 lists these old calls and the function requests that have superseded them.

Although MS-DOS still includes these old system calls, they should not be used unless a program must maintain backward-compatibility with earlier versions of MS-DOS.

Table 1.13
Old System Calls and Their Replacements

Old System Call		Has Been Superseded By	
Code	Function	Code	Function
00H	Terminate Program	4CH	End Process

	0FH	Open File	3DH	Open Handle
	10H	Close File	3EH	Close Handle
	Old System Call		Has Been Superseded By	
	Code	Function	Code	Function
#	10H	Close File	3EH	Close Handle
	11H	Search for First Entry	4EH	Find First File
	12H	Search for Next Entry	4FH	Find Next File
	13H	Delete File	41H	Delete Directory Entry
	14H	Sequential Read	3FH	Read Handle
	15H	Sequential Write	40H	Write Handle
	16H	Create File	3CH	Create Handle
			5AH	Create Temporary File
			5BH	Create New File
	17H	Rename File	56H	Change Directory Entry
	21H	Random Read	3FH	Read Handle
	Old System Call		Has Been Superseded By	
	Code	Function	Code	Function
#	21H	Random Read	3FH	Read Handle
	22H	Random Write	40H	Write Handle
	23H	Get File Size	42H	Move File Pointer
	24H	Set Relative Record	42H	Move File Pointer
	26H	Create New PSP	4BH	Load and Execute Program
	27H	Random Block Read	42H	Move File Pointer
			3FH	Read Handle
	28H	Random Block Write	42H	Move File Pointer
			40H	Write Handle
	Code	Interrupt	Code	Function
	20H	Program Terminate	4CH	End Process
	Old System Call		Has Been Superseded By	
	Code	Function	Code	Function
#	20H	Program Terminate	4CH	End Process
	27H	Terminate But Stay Resident	31H	Keep Process

1.9.1 File Control Block (FCB)

The old file-related function requests require that a program maintain a File Control Block (FCB) for each file; this control block contains such information as a file's name, size, record length, and pointer to current record. MS-DOS does most of this housekeeping for the newer, handle-oriented function requests.

Some descriptions of the old function requests refer to unopened and opened FCBs. An unopened FCB contains only a drive specifier and filename. An opened FCB contains all fields filled by Function 0FH (Open File).

The Program Segment Prefix (PSP) includes room for two FCBs at offsets 5CH and 6CH. For a description of how to use the PSP and FCB calls, see Chapter 4, "MS-DOS Control Blocks and Work Areas," Table 1.14 describes the FCB fields.

Table 1.14
Format of the File Control Block (FCB)

Offset Hex	Dec	Bytes	Field
00H	0	1	Drive Number
01H	1	8	Filename
09H	9	3	Extension
0CH	12	2	Current Block
0EH	14	2	Record Size
10H	16	4	File Size
14H	20	2	Date of Last Write
16H	22	2	Time of Last Write
18H	24	8	Reserved
Offset Hex	Dec	Bytes	Field
18H	24	8	Reserved
20H	32	1	Current Record
21H	33	4	Relative Record

Fields of the FCB

Drive Number (offset 00H): Specifies the disk drive; 1 means drive A and 2 means drive B. If you use the FCB to create or open a file, you can set this field to 0 to specify the default drive; Function 0FH (Open File) sets the field to the number of the default drive.

Filename (offset 01H): Eight characters, left-aligned and padded (if necessary) with blanks. If you specify a reserved device name (such as PRN), do not put a colon at the end.

Extension (offset 09H): Three characters, left-aligned and padded (if necessary) with blanks. This field can be all blanks (no extension).

Current Block (offset 0CH): Points to the block (group of 128 records) that contains the current record. This field and the Current Record field (offset 1FH) make up the record pointer. This field is set to zero by the Open File system call.

Record Size (offset 0EH): The size of a logical record, in bytes. Set to 128 by the Open File system call. If the record size is not 128 bytes, you must set this field after opening the file.

File Size (offset 0FH): The size of the file, in bytes. The first word of this 4-byte field is the low-order part of the size.

Date of Last Write (offset 13H): The date the file was created or last updated. The year, month, and day are mapped into two bytes as follows:

```
Off     set 14H          Offset 13H
|Y|Y|Y|Y|Y|Y|Y|M|   |M|M|M|D|D|D|D|D|
15              9   8    5 4        0
```

Time of Last Write (offset 15H): The time the file was created or last

updated. The hour, minutes, and seconds are mapped into two bytes as follows:

```
Offset 16H          Offset 15H
|H|H|H|H|H|M|M|M|   |M|M|M|S|S|S|S|S|
15      11 10            5 4        0
```

Reserved (offset 17H): These fields are reserved for use by MS-DOS.

Current Record (offset 1FH): Points to one of the 128 records in the current block. This field and the Current Block field (offset 0CH) make up the record pointer. The Open File system call does not initialize this field. You must set it before doing a sequential read or write to the file.

Relative Record (offset 20H): Points to the currently selected record, counting from the beginning of the file (starting with 0). The Open File system call does not initialize this field. You must set it before doing a random read or write to the file. If the record size is less than 64 bytes, both words of this field are used; if the record size is 64 bytes or more, only the first three bytes are used.

.....
Note
  If you use the FCB at offset 5CH of the Program Segment Prefix, the last byte of the Relative Record field is the first byte of the unformatted parameter area that starts at offset 80H. This is the default Disk Transfer Area.
.....

Extended FCB

The Extended File Control Block is used to create or search for directory entries of files with special attributes. It adds the following 7-byte prefix to the FCB:

Name	Bytes	Offset
Flag byte (FFH)	1	07H
Reserved	5	06H
Attribute byte	1	01H

File attributes are described earlier in this chapter in Section 1.5.5, "File Attributes."

.....
Note
  You must remember to point to the beginning of the extended FCB if you are using Functions 0FH-16H with extended FCBs.
.....

1.10 Using the System Calls

The remainder of this chapter describes how to use the system calls in application programs, and it lists the calls in numeric and alphabetic order, describing each call in detail.

1.10.1 Issuing an Interrupt

MS-DOS reserves Interrupts 28H through 3FH for its own use, and

maintains the table of interrupt-handler addresses (the vector table) in locations 80H-FCH. Also, in case you need to write your own routines for three particular MS-DOS interrupt handlers (Program Terminate, CONTROL-C, and Critical Error), this chapter includes descriptions of each. Function requests have superseded most of these interrupts.

To issue an interrupt, move any required data into the registers and give the INT instruction with the number of the interrupt you want.

1.10.2 Calling a Function Request

A function request is an MS-DOS routine for managing system resources. Use the following procedure to call a function request:

1. Move any required data into the registers.
2. Move the function number into AH.
3. Move the action code, if required, into AL.
4. Issue Interrupt 21H.

1.10.3 Using the Calls from a High-Level Language

The system calls can be executed from any high-level language whose modules can be linked with assembly-language modules. In addition to this linking technique, you can:

- Use the DOSXQQ function of Pascal-86 to call a function request directly.
- Use the CALL statement or USER function to execute the required assembly-language code from the BASIC interpreter.

1.10.4 Treatment of Registers

When MS-DOS takes control after a function request, it switches to an internal stack, and preserves any registers not used to return information (except AX). The calling program's stack must be large enough to accommodate the interrupt system--at least 128 bytes in addition to other needs.

1.10.5 Handling Errors

Most of the function requests introduced with version 2.0 or later set the Carry flag if there is an error, identifying the specific error by returning a number in the AX register. Table 1.15 lists these error codes and their meanings.

Table 1.15
Error Codes Returned in AX

Code	Meaning

Code Meaning

```
        1       Invalid function code
        2       File not found
        3       Path not found
        4       Too many open files (no open handles left)
        5       Access denied
        6       Invalid handle
        7       Memory control blocks destroyed
        8       Insufficient memory
        9       Invalid memory block address

       10       Invalid environment
       11       Invalid format
       12       Invalid access code
       13       Invalid data
       14       Reserved
       15       Invalid drive
       16       Attempt to remove the current directory
       17       Not same device
       18       No more files
       Code     Meaning
#      18       No more files
       19       Disk is write-protected

       20       Bad disk unit
       21       Drive not ready
       22       Invalid disk command
       23       CRC error
       24       Invalid length (disk operation)
       25       Seek error
       26       Not an MS-DOS disk
       27       Sector not found
       28       Out of paper
       29       Write fault

       30       Read fault
       31       General failure
       32       Sharing violation
       33       Lock violation
       34       Wrong disk
       35       FCB unavailable
       Code     Meaning
#      35       FCB unavailable
       36-49    Reserved

       50       Network request not supported
       51       Remote computer not listening
       52       Duplicate name on network
       53       Network name not found
       54       Network busy
       55       Network device no longer exists
       56       Net BIOS command limit exceeded
       57       Network adapter hardware error
       58       Incorrect response from network
       59       Unexpected network error

       60       Incompatible remote adapter
       61       Print queue full
       62       Queue not full
       63       Not enough space for print file
       64       Network name was deleted
       65       Access denied
       Code     Meaning
#      65       Access denied
```

```
      66      Network device type incorrect
      67      Network name not found
      68      Network name limit exceeded
      69      Net BIOS session limit exceeded

      70      Temporarily paused
      71      Network request not accepted
      72      Print or disk redirection is paused
      73-79   Reserved

      80      File exists
      81      Reserved
      82      Cannot make
      83      Interrupt 24 failure
      84      Out of structures
      85      Already assigned
      86      Invalid password
      87      Invalid parameter
      88      Net write fault
      Code    Meaning
#     88      Net write fault
```

To handle error conditions, put the following statement immediately after calls that return errors:

```
JC <error>
```

<Error> represents the label of an error-handling routine that gets the specific error condition by checking the value in AX. This routine then takes appropriate action.

Some of the older system calls return a value in a register that specifies whether the operation was successful. To handle such errors, check the error code and take the appropriate action.

Extended Error Codes

Versions of MS-DOS after 2.0 have added new error messages. Any programs that use the older system calls cannot use these new error messages. To avoid incompatibility, MS-DOS maps these new error codes to the old error code that most closely matches the new one.

Function 59H (Get Extended Error) has been added so that these new calls can be used. It provides as much detail as possible about the most recent error code returned by MS-DOS. The description of Function 59H lists the new, more detailed error codes and shows how to use this function request.

1.10.6 System Call Descriptions

Most system calls require that you move information into one or more registers before issuing the call that returns information in the registers. The description of each system call in this chapter includes the following:

- A diagram of the 8088 registers that shows their contents before and after the system call
- A more complete description of the register contents required before the system call

- A description of the processing performed

- A more complete description of the register contents after the system call

- An example of how to use the system call

The following figure is a sample illustration of the 8088 registers, showing how the information is presented. Shaded areas indicate that the register receives or returns information used by the call.

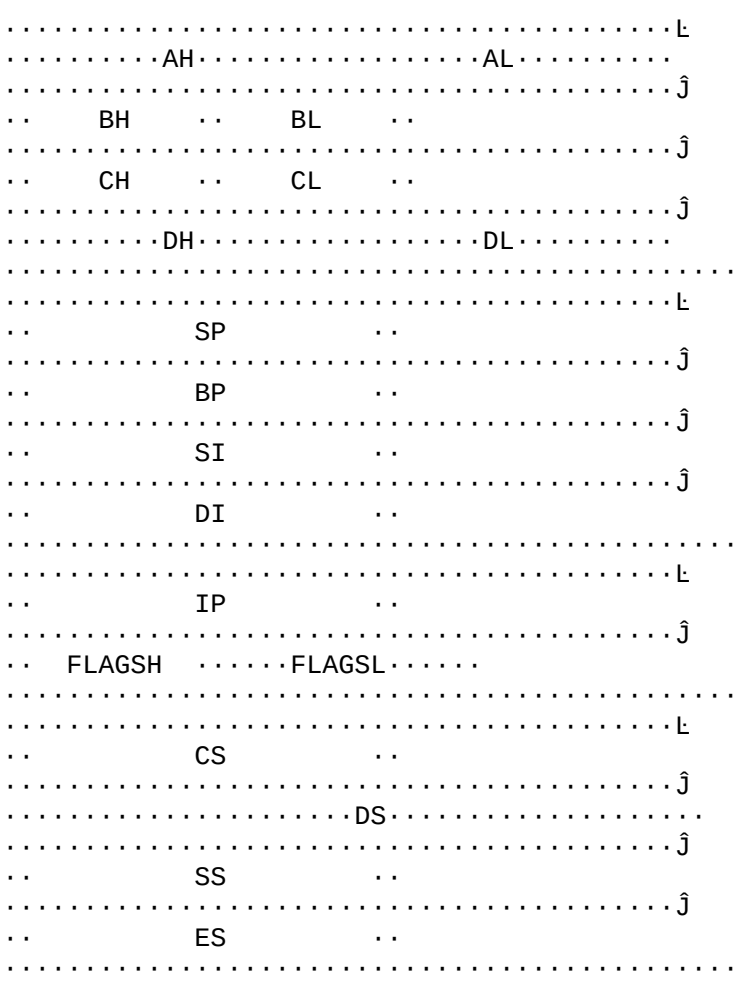


Figure 1.1 Example of the 8088 Registers

1.10.6.1 Sample Programs

The sample programs show only data declarations and the code that you need to use the system calls. Unless stated otherwise, each example assumes a common program skeleton that defines the segments and returns control to MS-DOS. Each sample program is intended to be executed as a .com file. Figure 1.2 shows a complete sample program. The unshaded portion shows what appears in this chapter; the shaded portions are the common skeleton.

```
.........
code       segment
           assume  cs:code,ds:code,es:nothing,ss:nothing
           org     100H
start:     jmp     begin
;
```

```
filename   db      "b:\textfile.asc",0
buffer     db      129 dup (?)
handle     dw      ?
;
begin:     open_handle filename,0        ; Open the file
           jc      error_open            ; Routine not shown
           mov     handle,ax             ; Save handle
read_line: read_handle handle,buffer,128 ; Read 128 bytes
           jc      error_read            ; Routine not shown
           cmp     ax,0                  ; End of file?
           je      return                ;   Yes, go home
           mov     bx,ax                 ;   No, AX bytes read
           mov     buffer[bx],"$"        ; To terminate string
           display buffer                ; See Function 09H
           jmp     read_line             ; Get next 128 bytes

return:    end_process 0                 ; Return to MS-DOS
last_inst:                               ; To mark next byte
;
code       ends
           end     start
..........
```

Figure 1.2 Sample Program with Common Skeleton

A macro has been defined for each system call to allow the examples to be more complete programs, rather than isolated uses of the system calls. These macros, plus some general-purpose ones, are used in the sample programs. For instance, the sample program in the preceding figure includes four such macros: open_handle, read_handle, display, and end_process. All the macro definitions are listed at the end of this chapter.

The macros assume the environment for a .com program as described in Chapter 4; in particular, they assume that all the segment registers contain the same value. To conserve space, the macros generally leave error checking to the main code and do not protect registers. This keeps the macros short, yet useful. You may find that such macros are a convenient way to include system calls in your assembly-language programs.

1.10.6.2 Error Handling in Sample Programs

Whenever a system call returns an error code, the sample program shows a test for the error condition and a jump to an error routine. To conserve space, the error routines themselves aren't shown. Some error routines might simply display a message and continue processing. For more serious errors, the routine might display a message and end the program (performing any required housekeeping, such as closing files).

Tables 1.16 through 1.19 list the Interrupts and Function Requests in numeric and alphabetic order.

Table 1.16
MS-DOS Interrupts, Numeric Order

Interrupt	Description
Interrupt	Description
20H	Program Terminate
21H	Function Request
22H	Terminate Process Exit Address

23H	CONTROL-C Handler Address
24H	Critical-Error-Handler Address
25H	Absolute Disk Read
26H	Absolute Disk Write
27H	Terminate But Stay Resident
28H-3FH	Reserved

Table 1.17
MS-DOS Interrupts, Alphabetic Order

Description	Interrupt
Absolute Disk Read	25H
Absolute Disk Write	26H

Description Interrupt
Absolute Disk Write 26H

CONTROL-C Handler Address	23H
Critical-Error-Handler Address	24H
Function Request	21H
Program Terminate	20H
Reserved	28H-3FH
Terminate Process Exit Address	22H
Terminate But Stay Resident	27H

Table 1.18
MS-DOS Function Requests, Numeric Order

Function	Description
00H	Terminate Program
01H	Read Keyboard And Echo
02H	Display Character
03H	Auxiliary Input

Function Description
03H Auxiliary Input

04H	Auxiliary Output
05H	Print Character
06H	Direct Console I/O
07H	Direct Console Input
08H	Read Keyboard
09H	Display String
0AH	Buffered Keyboard Input
0BH	Check Keyboard Status
0CH	Flush Buffer, Read Keyboard
0DH	Reset Disk
0EH	Select Disk
0FH	Open File
10H	Close File
11H	Search For First Entry
12H	Search For Next Entry
13H	Delete File
14H	Sequential Read
15H	Sequential Write
16H	Create File

Function Description
16H Create File

17H	Rename File
18H	Reserved
19H	Get Current Disk
1AH	Set Disk Transfer Address

```
      1BH           Get Default Drive Data
      1CH           Get Drive Data
      1DH-20H       Reserved
      21H           Random Read
      22H           Random Write
      23H           Get File Size
      24H           Set Relative Record
      25H           Set Interrupt Vector
      26H           Create New PSP
      27H           Random Block Read
      28H           Random Block Write
      29H           Parse File Name
      2AH           Get Date
      2BH           Set Date
      2CH           Get Time
      Function      Description
#     2CH           Get Time
      2DH           Set Time
      2EH           Set/Reset Verify Flag
      2FH           Get Disk Transfer Address
      30H           Get MS-DOS Version Number
      31H           Keep Process
      32H           Reserved
      33H           CONTROL-C Check
      34H           Reserved
      35H           Get Interrupt Vector
      36H           Get Disk Free Space
      37H           Reserved
      38H           Get/Set Country Data
      39H           Create Directory
      3AH           Remove Directory
      3BH           Change Current Directory
      3CH           Create Handle
      3DH           Open Handle
      3EH           Close Handle
      3FH           Read Handle
      Function      Description
#     3FH           Read Handle
      40H           Write Handle
      41H           Delete Directory Entry (Unlink)
      42H           Move File Pointer
      43H           Get/Set File Attributes (Chmod)
      4400H,4401H   IOCtl Data
      4402H,4403H   IOCtl Character
      4404H,4405H   IOCtl Block
      4406H,4407H   IOCtl Status
      4408H         IOCtl Is Changeable
      4409H         IOCtl Is Redirected Block
      440AH         IOCtl Is Redirected Handle
      440BH         IOCtl Retry
      440CH         Generic IOCtl (for code page functions)
      440DH         Generic IOCtl (for devices)
      440EH         Get IOCtl Drive Map
      440FH         Set IOCtl Drive Map
      45H           Duplicate File Handle
      46H           Force Duplicate File Handle
      47H           Get Current Directory
      Function      Description
#     47H           Get Current Directory
      48H           Allocate Memory
      49H           Free Allocated Memory
      4AH           Set Block
      4BH           Load and Execute Program
      4B03H         Load Overlay
```

4CH	End Process
4DH	Get Return Code of Child Process
4EH	Find First File
4FH	Find Next File
50H-53H	Reserved
54H	Get Verify State
55H	Reserved
56H	Change Directory Entry
57H	Get/Set Date/Time of File
58H	Get/Set Allocation Strategy
59H	Get Extended Error
5AH	Create Temporary File
5BH	Create New File
5C00H	Lock

Function Description
5C00H Lock
5C01H Unlock
5DH Reserved
5E00H Get Machine Name
5E02H Printer Setup
5F02H Get Assign-List Entry
5F03H Make Assign-List Entry
5F04H Cancel Assign-List Entry
60H-61H Reserved
62H Get PSP
63H,64H Reserved
65H Get Extended Country Information
66H Get/Set Global Code Page
67H Set Handle Count
68H Commit File
69H-7FH Reserved

Table 1.19
MS-DOS Function Requests, Alphabetic Order

Description	Interrupt
Allocate Memory	48H
Auxiliary Input	03H
Auxiliary Output	04H
Buffered Keyboard Input	0AH
Cancel Assign-List Entry	5F04H
Change Current Directory	3BH
Change Directory Entry	56H
Check Keyboard Status	0BH
Close File	10H
Close Handle	3EH
Commit FIle	68H
CONTROL-C Check	33H
Create Directory	39H
Create File	16H
Create Handle	3CH
Create New File	5BH
Create New PSP	26H

Description Interrupt
Create New PSP 26H
Create Temporary File 5AH
Delete Directory Entry (Unlink) 41H
Delete File 13H
Direct Console I/O 06H
Direct Console Input 07H
Display Character 02H

```
      Display String                              09H
      Duplicate File Handle                       45H
      End Process                                 4CH
      Find First File                             4EH
      Find Next File                              4FH
      Flush Buffer, Read Keyboard                 0CH
      Force Duplicate File Handle                 46H
      Free Allocated Memory                       49H
      Generic IOCtl (for devices)                 440DH
      Generic IOCtl (for code page functions)     440CH
      Get Assign-List Entry                       5F02H
      Get Current Directory                       47H
      Get Current Disk                            19H
      Description                                 Interrupt
#     Get Current Disk                            19H
      Get Date                                    2AH
      Get Default Drive Data                      1BH
      Get Disk Free Space                         36H
      Get Disk Transfer Address                   2FH
      Get Drive Data                              1CH
      Get Extended Country Information            65H
      Get Extended Error                          59H
      Get File Size                               23H
      Get Interrupt Vector                        35H
      Get IOCtl Drive Map                         440EH
      Get Machine Name                            5E00H
      Get MS-DOS Version Number                   30H
      Get PSP                                     62H
      Get Return Code of Child Process            4DH
      Get Time                                    2CH
      Get Verify State                            54H
      Get/Set Allocation Strategy                 58H
      Get/Set Country Data                        38H
      Get/Set Date/Time Of File                   57H
      Description                                 Interrupt
#     Get/Set Date/Time Of File                   57H
      Get/Set File Attributes (Chmod)             43H
      Get/Set Global Code Page                    66H
      IOCtl Block                                 4404H,4405H
      IOCtl Character                             4402H,4403H
      IOCtl Data                                  4400H,4401H
      IOCtl Is Changeable                         4408H
      IOCtl Is Redirected Block                   4409H
      IOCtl Is Redirected Handle                  440AH
      IOCtl Retry                                 440BH
      IOCtl Status                                4406H,4407H
      Keep Process                                31H
      Load and Execute Program                    4BH
      Load Overlay                                4B03H
      Lock                                        5C00H
      Make Assign-List Entry                      5F03H
      Move File Pointer                           42H
      Open File                                   0FH
      Open Handle                                 3DH
      Parse File Name                             29H
      Description                                 Interrupt
#     Parse File Name                             29H
      Print Character                             05H
      Printer Setup                               5E02H
      Random Block Read                           27H
      Random Block Write                          28H
      Random Read                                 21H
      Random Write                                22H
      Read Handle                                 3FH
```

	Read Keyboard	08H
	Read Keyboard And Echo	01H
	Remove Directory	3AH
	Rename File	17H
	Reserved	18H
	Reserved	1DH-20H
	Reserved	32H
	Reserved	34H
	Reserved	37H
	Reserved	50H-53H
	Reserved	55H
	Reserved	5DH
	Description	Interrupt
#	Reserved	5DH
	Reserved	60H-61H
	Reserved	63H, 64H
	Reserved	69H-7FH
	Reset Disk	0DH
	Search for First Entry	11H
	Search for Next Entry	12H
	Select Disk	0EH
	Sequential Read	14H
	Sequential Write	15H
	Set Block	4AH
	Set Date	2BH
	Set Disk Transfer Address	1AH
	Set Handle Count	67H
	Set Interrupt Vector	25H
	Set IOCtl Drive Map	440FH
	Set Relative Record	24H
	Set Time	2DH
	Set/Reset Verify Flag	2EH
	Terminate Program	00H
	Description	Interrupt
#	Terminate Program	00H
	Unlock	5C01H
	Write Handle	40H

A detailed description of each system call follows. These calls are listed in numeric order, interrupts first, followed by function requests.

.....

Note

Unless stated otherwise, in the system call descriptions--both text and code--all numbers are in hexadecimal.

.....

1.11 Interrupts

The following pages describe Interrupts 20H-27H.

Program Terminate (Interrupt 20H)

Call:

CS

Segment address of Program Segment Prefix

Return:

None

Comments:

Interrupt 20H terminates the current process and returns control to its parent process. It also closes all open file handles and clears the disk cache. When this interrupt is issued, CS must contain the segment address of the Program Segment Prefix.

Interrupt 20H is provided only for compatibility with MS-DOS versions prior to 2.0. New programs should use Function 4CH (End Process), which permits returning a completion code to the parent process and does not require CS to contain the segment address of the Program Segment Prefix.

The following exit addresses are restored from the Program Segment Prefix:

Offset	Exit Address
0AH	Program terminate
0EH	CONTROL-C
12H	Critical error

All file buffers are flushed to disk.

Note
  You should close all files that have changed in length before issuing this interrupt. If you do not close a changed file, its length may not be recorded correctly in the directory. See Functions 10H and 3EH for a description of the Close File system calls. If sharing is loaded, you should remove all locks before using Interrupt 20H. See Function 5CH (Lock) for more information.

Macro Definition:

```
terminate  macro
           int 20H
           endm
```

Example:

The following program displays a message and returns to MS-DOS. It uses only the opening portion of the sample program skeleton shown in Figure 1.2:

```
message db "displayed by INT20H example". 0DH, 0AH, "$"
;
begin:  display message  ;see Function 09H
        terminate        ;THIS INTERRUPT
code    ends
        end     start
```

Function Request (Interrupt 21H)

Call:

AH
  Function number

Other registers
  As specified in individual function

Return:

None.

Comments:

As specified in individual function. Interrupt 21H causes MS-DOS to carry out the function request whose number is in AH. See Section 1.12, "Function Requests," for a description of the MS-DOS functions.

Example:

To call the Get Time function:

```
mov   ah,2CH          ;Get Time is Function 2CH
int   21H             ;MS-DOS function request
```

Terminate Process Exit Address (Interrupt 22H)

This interrupt may be issued only by MS-DOS; user programs must never issue it. If you must write your own terminate interrupt handler, use Function 35H (Get Interrupt Vector) to get the address of the standard routine, save the address, then use Function 25H (Set Interrupt Vector) to change the Interrupt 22H entry in the vector table so that it points to your routine.

When a program terminates, MS-DOS transfers control to the routine that starts at the address in the Interrupt 22H entry in the vector table. When MS-DOS creates a program segment, it copies this address into the Program Segment Prefix, starting at offset 0AH.

CONTROL-C Handler Address (Interrupt 23H)

When you type CONTROL-C or CONTROL-BREAK (on IBM-compatibles), MS-DOS transfers control as soon as possible to the routine that starts at the address in the Interrupt 23H entry in the vector table. When MS-DOS creates a program segment, it copies the address currently in the interrupt table into the Program Segment Prefix, starting at offset 0EH.

This interrupt may be issued only by MS-DOS; user programs must never issue it. If you must write your own CONTROL-C interrupt handler, use Function Request 35H (Get Interrupt Vector) to get the address of the standard routine, save the address, then use Function Request 25H (Set Interrupt Vector) to change the Interrupt 23H entry in the vector table to point to your routine.

If the CONTROL-C routine preserves all registers, it can end with an IRET instruction (return from interrupt) to continue program execution. If a user-written interrupt program returns with a long return, the program uses the carry flag to determine whether or not the program will abort.

If the carry flag is set, it will abort; otherwise, execution will continue as with a return by IRET.

If a user-written CONTROL-BREAK routine interrupts function calls 09H, 0AH, or buffered I/O, and if it continues execution with an IRET, then I/O continues from the start of the line. MS-DOS always outputs a CONTROL-C to the screen when it issues an Interrupt 23H. There is no way to turn this off.

When the interrupt occurs, all registers are set to the value they had when the original call to MS-DOS was made. There are no restrictions on what a CONTROL-C handler can do--including calling MS-DOS functions--as long as the program restores the registers.

If a CONTROL-C interrupts Function 09H or 0AH (Display String or Buffered Keyboard Input), the three-byte sequence 03H-0DH-0AH (usually displayed as C followed by a carriage-return) is sent to the display and the function resumes at the beginning of the next line.

Suppose a program uses Function 4BH (Load and Execute Program) to create a second Program Segment Prefix and execute a second program, which then changes the CONTROL-C address in the vector table. MS-DOS restores this CONTROL-C vector to its original value before returning control to the calling program.

Critical-Error-Handler Address (Interrupt 24H)

If a critical error occurs during execution of an I/O function request (this often means a fatal disk error), MS-DOS transfers control to the routine at the address in the Interrupt 24H entry in the vector table. When MS-DOS creates a program segment, it copies this address into the Program Segment Prefix, starting at offset 12H.

This interrupt may be issued only by MS-DOS; user programs must never issue it. If you must write your own critical-error interrupt handler, use Function 35H (Get Interrupt Vector) to get the address of the standard routine, save the address, then use Function 25H (Set Interrupt Vector) to change the Interrupt 24H entry in the vector table to point to your routine.

MS-DOS does not issue Interrupt 24H if a failure occurs during execution Interrupt 25H (Absolute Disk Read) or Interrupt 26H (Absolute Disk Write). A command.com error routines handles these errors. This routine retries the disk operation, then gives you the choice of aborting the operation, retrying it, allowing the system call to fail and the application process to continue, or ignoring the error.

The following topics describe the requirements of an Interrupt 24H routine, including the error codes, registers, and stack.

1.11.1 Conditions upon Entry

After retrying an I/O error five times, MS-DOS issues Interrupt 24H, unless a File Allocation Table (FAT) or directory sector is involved. In those cases, DOS performs three retries. The interrupt handler receives control with interrupts disabled. AX and DI contain error codes, and BP contains the offset (to the segment address in SI) of a Device Header control block that describes the device on which the error occurred.

1.11.2 Requirements for an Interrupt 24H Handler

To issue the "Abort, Retry, Fail or Ignore" prompt to a user, a user-written critical-error handler should first push the flags and execute a FAR call to the address of the standard Interrupt 24H handler (the user program that changed the Interrupt 24H vector also should have saved this address). After a user responds to the prompt, MS-DOS returns control to the user-written routine.

.....
Note
  There are source applications which will have trouble handling critical errors, since this changes the stack frame.
.....

The error handler can then do its processing, but before it does anything else it must preserve BX, CX, DX, DS, ES, SS, and SP. Also, the error handler may use only function calls 01-0CH (inclusive) and 59H (if it uses any others, the error handler destroys the MS-DOS stack and leaves MS-DOS in an unstable state). The contents of the Device Header should not be changed.

It is recommended that Interrupt 24H routine fail critical errors and let the application test for an extended error code when the Interrupt 21H routine returns.

User Stack

This call uses the user stack that contains the following (starting with the top of the stack):

```
IP     MS-DOS registers from issuing Interrupt 24H
CS
FLAGS

AX     User registers at time of original
BX     INT 21H
CX
DX
SI
DI
BP
DS
ES

IP     From the original INT 21H
CS     from the user to MS-DOS
FLAGS
```

The registers are set such that if the user-written error handler issues an IRET, MS-DOS responds according to the value in AL:

AL	Action
0	Ignore the error.
1	Retry the operation.
2	Abort the program by issuing Interrupt 23H.
3	Fail the system call that is in progress.

Note that the ignore option may cause unexpected results, such as causing MS-DOS to behave as if an operation had completed successfully.

Disk Error Code in AX

If bit 7 of AH is 0, the error occurred on a disk drive. AL contains the failing drive (0=A, 1=B, etc.). Bit 0 of AH specifies whether the error occurred during a read or write operation (0=read, 1=write), and bits 1 and 2 of AH identify the area of the disk where the error occurred:

Bits 1-2	Location of error
00	MS-DOS area
01	File Allocation Table
10	Directory
11	Data area

Bits 3-5 of AH specify valid responses to the error prompt:

Bit	Value	Response
3	0	Fail not allowed
	1	Fail allowed
4	0	Retry not allowed
	1	Retry allowed
5	0	Ignore not allowed
	1	Ignore allowed

If you specify Retry but it isn't allowed, MS-DOS changes it to Fail. If you specify Ignore but it isn't allowed, MS-DOS changes it to Fail. If you specify Fail but it isn't allowed, MS-DOS changes it to Abort. The Abort response is always allowed.

Other Device Error Code in AX

If bit 7 of AH is 1, either the memory image of the File Allocation Table (FAT) is bad or an error occurred on a character device. The device header pointed to by BP:SI contains a WORD of attribute bits that identify the type of device and, therefore, the type of error.

The word of attribute bits is at offset 04H of the Device Header. Bit 15 specifies the type of device (0=block, 1=character).

If bit 15 is 0 (block device), the error was a bad memory image of the FAT.

If bit 15 is 1 (character device), the error was on a character device. DI contains the error code, the contents of AL are undefined, and bits 0-3 of the attribute word have the following meaning:

Bit	Meaning if Set
0	Current standard input
1	Current standard output
2	Current null device
3	Current clock device

See Chapter 2, "MS-DOS Device Drivers," for a complete description of the Device Header control block.

Error Code in DI

The high byte of DI is undefined. The low byte contains the following error codes:

Error code	Description

0	Attempt to write on write-protected disk
1	Unknown unit
2	Drive not ready
3	Unknown command
4	CRC error in data
5	Bad drive request structure length
6	Seek error
7	Unknown media type
8	Sector not found
9	Printer out of paper
A	Write fault
B	Read fault
C	General failure

A user-written Interrupt 24H handler can use Function 59H (Get Extended Error) to get detailed information about the error that caused the interrupt to be issued.

Absolute Disk Read (Interrupt 25H)

Call:

AL
  Drive number
DS:BX
  Disk Transfer Address
CX
  Number of sectors
DX
  Beginning relative sector

Return:

AL
  Error code if CF=1
Flags
  CF = 0 if successful
     = 1 if not successful

Comments:

The registers must contain the following:

Register	Contents
AL	Drive number (0=A, 1=B, etc.)
BX	Offset of Disk Transfer Address (from segment address in DS)
CX	Number of sectors to read
DX	Beginning relative sector

Warning
  Avoid using this function unless absolutely necessary. Instead, you should access files through normal MS-DOS function requests. There is no guarantee of upward compatibility for the Absolute Disk I/O in future releases of MS-DOS.

Interrupt 25H transfers control to the device driver and reads from the disk to the Disk-Transfer Address the number of sectors specified in CX.

The interrupt has the same requirements as and processes identically to Interrupt 26H (Absolute Disk Write), except that it reads data rather than writes it. Also, since this interrupt does not check your input parameters too closely, make sure they are reasonable. If you use unreasonable parameters, you may get strange results or cause your system to crash.

.....
Note
  This call destroys all registers except the segment registers. So before issuing the interrupt, save any registers that your program uses.
.....

The system pushes the flags at the time of the call; they are still there upon return. To prevent uncontrolled growth, be sure to pop the stack upon return.

If the disk operation is successful, the Carry Flag (CF) is 0. If the disk operation is not successful, CF is 1 and AL contains the MS-DOS error code (see Interrupt 24H earlier in this section for the codes and their meanings).

Macro Definition:

```
abs_disk_read  macro  disk,buffer,num_sectors,first_sector
               mov    al,disk
               mov    bx,offset buffer
               mov    cx,num_sectors
               mov    dx,first_sector
               int    25H
               popf
               endm
```

Example:

The following program copies the contents of a single-sided disk in drive A to the disk in drive B.

```
prompt     db   "Source in A, target in B",0DH,0AH
           db   "Any key to start. $"
first      dw    0
buffer     db    60 dup (512 dup (?))  ;60 sectors
;
begin:     display prompt         ;see Function 09H
           read_kbd               ;see Function 08H
           mov     cx,6           ;copy 6 groups of
                                  ;60 sectors
copy:      push    cx             ;save the loop counter
           abs_disk_read  0,buffer,60,first  ;THIS INTERRUPT
           abs_disk_write 1,buffer,60,first  ;see INT 26H
           add  first,60          ;do the next 60 sectors
           pop  cx                ;restore the loop counter
           loop copy
```

Absolute Disk Write (Interrupt 26H)

Call:

AL
  Drive number
DS:BX

  Disk Transfer Address
CX
  Number of sectors
DX
  Beginning relative sector

Return:

AL
  Error code if CF = 1
FLAGS
  CF   = 0 if successful
          = 1 if not successful

Comments:

....
Warning
  Avoid using this function unless absolutely necessary. Instead, you
  should access files through normal MS-DOS function requests. There is
  no guarantee of upward compatibility for the Absolute Disk I/O in future
  releases of MS-DOS.
....

The registers must contain the following:

Register	Contents
AL	Drive number (0=A, 1=B, etc.)
BX	Offset of Disk Transfer Address (from segment address in DS)
CX	Number of sectors to write
DX	Beginning relative sector

This interrupt transfers control to MS-DOS. The number of sectors specified in CX is written from the Disk Transfer Address to the disk. Its requirements and processing are identical to Interrupt 25H (Absolute Disk Read), except data is written to the disk rather than read from it. Also, since Interrupt 26H does not check your input parameters too closely, make sure they are reasonable. If you use unreasonable parameters, you may get strange results or cause your system to crash.

....
Note
  This call destroys all registers except the segment registers. So before
  issuing the interrupt, be sure to save any registers your program uses.
....

The system pushes the flags at the time of the call; they are still there upon return. To prevent uncontrolled growth, be sure to pop the stack upon return.

If the disk operation is successful, the Carry Flag (CF) is 0. If the disk operation is not successful, CF is 1 and AL contains the MS-DOS error code (see Interrupt 24H for the codes and their meanings).

Macro Definition:

```
abs_disk_write  macro  disk,buffer,num_sectors,first_sector
                mov    al,disk
                mov    bx,offset buffer
                mov    cx,num_sectors
```

```
                mov    dx,first_sector
                int    26H
                popf
                endm
```

Example:

The following program copies the contents of a single-sided disk in drive A to the disk in drive B, verifying each write. It uses a buffer of 32K bytes.

```
off         equ   0
on          equ   1
;
prompt      db   "Source in A, target in B",0DH,0AH
            db   "Any key to start. $"
first       dw    0
buffer      db    60 dup (512 dup (?))  ;60 sectors
;
begin:      display prompt       ;see Function 09H
            read_kbd             ;see Function 08H
            verify  on           ;see Function 2EH
            mov     cx,6         ;copy 6 groups of 60 sectors
copy:       push    cx           ;save the loop counter
            abs_disk_read  0,buffer,60,first  ;see INT 25H
            abs_disk_write 1,buffer,60,first  ;THIS INTERRUPT
            add  first,60        ;do the next 60 sectors
            pop  cx              ;restore the loop counter
            loop copy
            verify  off          ;see Function 2EH
```

Terminate But Stay Resident (Interrupt 27H)

Call:

CS:DX
  Pointer to first byte following
  last byte of code.

Return:

None

Comments:

This interrupt is provided only for compatibility with MS-DOS versions prior to 2.0. Unless your resident program must be compatible with MS-DOS versions before 2.0, you should use Function 31H (Keep Process) to install it. Function 31H lets programs larger than 64K remain resident and allows return information to be passed.

However, Interrupt 27H, which is often used to install device-specific interrupt handlers, forces programs that are up to 64K to remain resident after they terminate.

DX must contain the offset (from the segment address in CS) of the first byte that follows the last byte of code in the program. When Interrupt 27H is executed, the program terminates and control returns to MS-DOS, but the program is not overlaid by other programs. Files left open are not closed.

When the interrupt is called, CS must contain the segment address of the Program Segment Prefix (the value of DS and ES when execution started).

.Exe programs that are loaded into high memory must not use this interrupt. Similarly, since it restores the Interrupt 22H, 23H, and 24H vectors, you should not use Interrupt 27H to install new CONTROL-C or critical-error handlers.

Macro Definition:

```
stay_resident  macro last_instruc
               mov   dx,offset last_instruc
               inc   dx
               int   27H
               endm
```

Example:

Since the most common use of Interrupt 27H is to install a machine-specific routine, there is no general example that applies. The macro definition, however, shows the calling syntax.

1.12 Function Requests

The following pages describe function calls 00H-68H.

Terminate Program (Function 00H)

Call:

AH = 00H
CS
  Segment address of
  Program Segment Prefix

Return:

None

Comments:

Function 00H performs the same function as Interrupt 20H. It terminates the current process and returns control to its parent process. It also closes all open file handles and clears the disk cache. When this interrupt is issued, CS must contain the segment address of the Program Segment Prefix.

The CS register must contain the segment address of the Program Segment Prefix before you call this interrupt.

The following exit addresses are restored from the specified offsets in the Program Segment Prefix:

Offset	Exit Address
.....	

```
0AH     Program terminate
0EH     CONTROL-C
12H     Critical error

All file buffers are flushed to disk.

..........
Warning
  Close all files that have changed in length before calling this function.
  If you do not close a changed file, its length is not correctly recorded
  in the directory. See Function 10H for a description of the Close File
  system call.
..........


Macro Definition:

terminate_program  macro
                   xor    ah,ah
                   int    21H
                   endm


Example:

The following program displays a message and returns to MS-DOS. It uses
only the opening portion of the sample program skeleton shown in Figure
1.2.

message db "Displayed by FUNC00H example", 0DH,0AH,"$"
;
begin:  display message    ;see Function 09H
        terminate_program  ;THIS FUNCTION
code    ends
        end    start


Read Keyboard and Echo (Function 01H)


Call:

AH = 01H


Return:

AL
  Character typed


Comments:

Function 01H waits for a character to be read from standard input, then
echoes the character to standard output and returns it in AL. If the
character is CONTROL-C, it executes Interrupt 23H.


Macro Definition:

read_kbd_and_echo  macro
                   mov  ah, 01H
                   int  21H
                   endm
```

Example:

The following program displays and prints characters as you type them. If you press the RETURN key, the program sends a linefeed/carriage-return sequence to both the display and the printer.

```
begin:     read_kbd_and_echo          ;THIS FUNCTION
           print_char   al            ;see Function 05H
           cmp          al,0DH        ;is it a CR?
           jne          begin         ;no, print it
           print_char   0AH           ;see Function 05H
           display_char 0AH           ;see Function 02H
           jmp          begin         ;get another character
```

Display Character (Function 02H)

Call:

AH = 02H
DL
  Character to be displayed

Return:

None

Comments:

Function 02H sends the character in DL to standard output. If you press CONTROL-C, it issues Interrupt 23H.

Macro Definition:

```
display_char macro   character
             mov     dl,character
             mov     ah,02H
             int     21H
             endm
```

Example:

The following program converts lowercase characters to uppercase before displaying them.

```
begin:     read_kbd                   ;see Function 08H
           cmp     al,"a"
           jl      uppercase          ;don't convert
           cmp     al,"z"
           jg      uppercase          ;don't convert
           sub     al,20H             ;convert to ASCII code
                                      ;for uppercase
uppercase: display_char al            ;THIS FUNCTION
           jmp     begin:             ;get another character
```

Auxiliary Input (Function 03H)

Call:

AH = 03H

Return:

AL
  Character from auxiliary device

Comments:

Function 03H waits for a character from standard auxiliary devices (AUX, COM1, COM2, COM3, COM4), then returns the character in AL. This system call does not return a status or error code.

If you press CONTROL-C, it issues Interrupt 23H.

Macro Definition:

```
aux_input  macro
           mov  ah,03H
           int  21H
           endm
```

Example:

The following program prints characters as soon as it receives them from the auxiliary device. It stops printing when it receives an end-of-file character (ASCII 26, or CONTROL-Z).

```
begin:     aux_input        ;THIS FUNCTION
           cmp   al,1AH     ;end of file?
           je    return     ;yes, all done
           print_char  al   ;see Function 05H
           jmp   begin      ;get another character
```

Auxiliary Output (Function 04H)

Call:

AH = 04H
DL
  Character for auxiliary device

Return:

None

Comments:

Function 04H sends the character in DL to standard auxiliary. This system call does not return a status or error code.

If you press CONTROL-C, it issues Interrupt 23H.

Macro Definition:

```
aux_output  macro  character
            mov  dl,character
            mov  ah,04H
            int  21H
            endm
```

Example:

The following program gets a series of strings of up to 80 bytes from the keyboard and sends each string to the auxiliary device. It stops when you type a null string (carriage-return only).

```
string   db    81 dup(?) ;see Function 0AH
;
begin:   get_string  80,string       ;see Function 0AH
         cmp  string[1],0            ;null string?
         je   return                 ;yes, all done
         mov  cx, word ptr string[1] ;get string length
         mov  bx,0                   ;set index to 0
send_it: aux_output string[bx+2]     ;THIS FUNCTION
         inc  bx                     ;bump index
         loop  send_it               ;send another character
         jmp  begin                  ;get another string
```

Print Character (Function 05H)

Call:

AH = 05H
DL
  Character for printer

Return:

None

Comments:

Function 05H sends the character in DL to the standard printer. If you press CONTROL-C, it issues Interrupt 23H. This function does not return a status or error code.

Macro Definition:

```
print_char macro character
           mov   dl,character
           mov   ah,05H
           int   21H
           endm
```

Example:

The following program prints a walking test pattern on the printer. It

stops if you press CONTROL-C.

```
line_num    db    0
;
begin:      mov   cx,60         ;print 60 lines
start_line: mov   bl,33         ;first printable ASCII
                                ;character (!)
            add   bl,line_num   ;to offset one character
            push  cx            ;save number-of-lines counter
            mov   cx,80         ;loop counter for line
print_it:   print_char bl       ;THIS FUNCTION
            inc   bl            ;move to next ASCII character
            cmp   bl,126        ;last printable ASCII
                                ;character (~)
            jl    no_reset      ;not there yet
            mov   bl,33         ;start over with (!)
no_reset:   loop  print_it      ;print another character
            print_char 0DH      ;carriage return
            print_char 0AH      ;linefeed
            inc   line_num      ;to offset 1st char. of line
            pop   cx            ;restore #-of-lines counter
            loop  start_line    ;print another line
```

Direct Console I/O (Function 06H)

Call:

AH = 06H
DL
  See text

Return:

AL
  If DL = FFH before call,
  then zero flag not set means AL
  has character from standard input.
  Zero flag set means there was not
  a character to get, and AL = 0.

Comments:

The action of Function 06H depends on the value in DL when the function is called:

Value in DL	Action
FFH	If a character has been read from standard input, it is returned in AL and the zero flag is cleared (0); if a character has not been read, the zero flag is set (1).
Not FFH	The character in DL is sent to standard output.

This function does not check for CONTROL-C.

Macro Definition:

```
dir_console_io  macro switch
                mov  dl,switch
```

```
                mov  ah,06H
                int  21H
                endm
```

Example:

The following program sets the system clock to 0 and displays the time continuously. When you type any character, the display freezes; when you type any character again, the clock is reset to 0 and the display starts again.

```
time      db  "00:00:00.00",0DH,0AH,"$"  ;see Function 09H
;                                        ;for explanation of $
;
begin:        set_time  0,0,0,0          ;see Function 2DH
read_clock:   get_time                   ;see Function 2CH
              CONVERT  ch,time           ;see end of chapter
              CONVERT  cl,time[3]        ;see end of chapter
              CONVERT  dh,time[6]        ;see end of chapter
              CONVERT  dl,time[9]        ;see end of chapter
              display  time              ;see Function 09H
              dir_console_io  FFH        ;THIS FUNCTION
              cmp      al,0              ;character typed?
              jne      stop              ;yes, stop timer
              jmp      read_clock        ;no, keep timer
                                         ;running
stop:         read_kbd                   ;see Function 08H
              jmp      begin             ;start over
```

Direct Console Input (Function 07H)

Call:

AH = 07H

Return:

AL
  Character from keyboard

Comments:

Function 07H waits for a character to be read from standard input, then returns it in AL. This function does not echo the character or check for CONTROL-C. (For a keyboard input function that echoes or checks for CONTROL-C, see Function 01H or 08H.)

Macro Definition:

```
dir_console_input  macro
                   mov  ah,07H
                   int  21H
                   endm
```

Example:

The following program prompts for a password (eight characters maximum) and

places the characters into a string without echoing them.

```
password  db  8 dup(?)
prompt    db "Password: $"       ;see Function 09H for
                                 ;explanation of $
begin:    display prompt         ;see Function 09H
          mov  cx,8              ;maximum length of password
          xor  bx,bx             ;so BL can be used as index
get_pass: dir_console_input      ;THIS FUNCTION
          cmp  al,0DH            ;was it a carriage return?
          je   return            ;yes, all done
          mov  password[bx],al   ;no, put character in string
          inc  bx                ;bump index
          loop get_pass          ;get another character
```

Read Keyboard (Function 08H)

Call:

AH = 08H

Return:

AL
  Character from keyboard

Comments:

Function 08H waits for a character to be read from standard input, then returns it in AL. If you press CONTROL-C, it issues Interrupt 23H. This function does not echo the character. (For a keyboard input function that echoes the character or checks for CONTROL-C, see Function 01H.)

Macro Definition:

```
read_kbd  macro
          mov   ah,08H
          int   21H
          endm
```

Example:

The following program prompts for a password (eight characters maximum) and places the characters into a string without echoing them.

```
password  db  8 dup(?)
prompt    db "Password: $"      ;see Function 09H
                                ;for explanation of $
begin:    display prompt        ;see Function 09H
          mov  cx,8             ;maximum length of password
          xor  bx,bx            ;BL can be an index
get_pass: read_kbd              ;THIS FUNCTION
          cmp  al,0DH           ;was it a carriage return?
          je   return           ;yes, all done
          mov  password[bx],al  ;no, put char. in string
          inc  bx               ;bump index
          loop get_pass         ;get another character
```

Display String (Function 09H)

Call:

AH = 09H
DS:DX
  Pointer to string to be displayed

Return:

None

Comments:

Function 09H sends to standard output a string that ends with "$" (the $ is not displayed).

The DX register must contain the offset (from the segment address in DS) of the string.

Macro Definition:

```
display  macro string
         mov   dx,offset string
         mov   ah,09H
         int   21H
         endm
```

Example:

The following program displays the hexadecimal code of the key that is typed.

```
table    db     "0123456789ABCDEF"
result   db     " - 00H",0DH,0AH,"$"  ;see text for
                                      ;explanation of $
begin:   read_kbd_and_echo             ;see Function 01H
         xor     ah,ah                 ;clear upper byte
         convert ax,16,result[3]       ;see end of chapter
         display result                ;THIS FUNCTION
         jmp     begin                 ;do it again
```

Buffered Keyboard Input (Function 0AH)

Call:

AH = 0AH
DS:DX
  Pointer to input buffer

Return:

None

Comments:

Function 0AH gets a string from standard input. DX must contain the offset (from the segment address in DS) of an input buffer of the following form:

Byte	Contents
1	Maximum number of characters in buffer, including the carriage return (you must set this value).
2	Actual number of characters typed, not counting the carriage return (the function sets this value).
3-n	Buffer; must be at least as long as the number in byte 1.

Characters are read from standard input and placed in the buffer beginning at the third byte until a RETURN character (ASCII 0DH) is read. If the buffer fills to one less than the maximum, additional characters read are ignored and ASCII 07H (Bel) is sent to standard output until a RETURN character is read. If you type the string at the console, it can be edited as it is being entered. If you press CONTROL-C, it issues Interrupt 23H.

MS-DOS sets the second byte of the buffer to the number of characters read (not counting the carriage return).

Macro Definition:

```
get_string  macro  limit,string
            mov    dx,offset string
            mov    string,limit
            mov    ah,0AH
            int    21H
            endm
```

Example:

The following program gets a 16-byte (maximum) string from the keyboard and fills a 24-line by 80-character screen with it.

```
buffer           label byte
max_length       db    ?               ;maximum length
chars_entered    db    ?               ;number of chars.
string           db    17 dup (?)      ;16 chars + CR
strings_per_line dw    0               ;how many strings
                                       ;fit on line
crlf             db    0DH,0AH
;
begin:           get_string 17,buffer   ;THIS FUNCTION
                 xor  bx,bx             ;so byte can be
                                        ;used as index
                 mov  bl,chars_entered  ;get string length
                 mov  buffer[bx+2],"$"  ;see Function 09H
                 mov  al,50H            ;columns per line
                 cbw
                 div  chars_entered     ;times string fits
                                        ;on line
                 xor  ah,ah             ;clear remainder
                 mov  strings_per_line,ax ;save col. counter
                 mov  cx,24             ;row counter
display_screen:  push cx                ;save it
                 mov  cx,strings_per_line ;get col. counter
```

```
display_line:    display  string        ;see Function 09H
                 loop display_line
                 display crlf           ;see Function 09H
                 pop  cx                ;get line counter
                 loop display_screen    ;display 1 more line
```

Check Keyboard Status (Function 0BH)

Call:

AH = 0BH

Return:

AL
  00H   = no characters in type-ahead buffer
  FFH   = characters in type-ahead buffer

Comments:

Function 0BH checks whether characters are available from standard input (if standard input has not been redirected, it checks the type-ahead buffer). If characters are available, AL returns FFH; if not, AL returns 0. If CONTROL-C is in the buffer, it issues Interrupt 23H.

Macro Definition:

```
check_kbd_status  macro
                  mov   ah,0BH
                  int   21H
                  endm
```

Example:

The following program displays the time continuously until you press any key:

```
time        db       "00:00:00.00",0DH,0AH,"$"
           .
           .
begin:      get_time                 ;see Function 2CH
            byte_to_dec ch,time      ;see end of chapter
            byte_to_dec cl,time[3]   ;see end of chapter
            byte_to_dec dh,time[6]   ;see end of chapter
            byte_to_dec dl,time[9]   ;see end of chapter
            display time             ;see Function 09H
            check_kbd_status         ;THIS FUNCTION
            cmp     al,0FFH          ;has a key been typed?
            je      return           ;yes, go home
            jmp     begin            ;no, keep displaying
                                     ;time
```

Flush Buffer, Read Keyboard (Function 0CH)

Call:

AH = 0CH
AL
  1, 6, 7, 8, or 0AH = the
  corresponding function
  is called.
  Any other value = no
  further processing.

Return:

AL
  00H = Type-ahead buffer was
  flushed; no other
  processing performed.

Comments:

Function 0CH empties the standard input buffer (if standard input has not been redirected, Function 0CH empties the type-ahead buffer). Further processing depends on the value in AL when the function is called.

AL	Action
1,6,7,8, or 0AH	The corresponding MS-DOS function is executed.
Any other value	No further processing; AL returns 0.

Macro Definition:

```
flush_and_read_kbd  macro switch
                    mov   al,switch
                    mov   ah,0CH
                    int   21H
                    endm
```

Example:

The following program both displays and prints characters as you type them. If you press the RETURN key, the program sends a carriage-return/linefeed sequence to both the display and the printer.

```
begin:     flush_and_read_kbd 1      ;THIS FUNCTION
           print_char   al           ;see Function 05H
           cmp          al,0DH       ;is it a carriage return?
           jne          begin        ;no, print it
           print_char   0AH          ;see Function 05H
           display_char 0AH          ;see Function 02H
           jmp          begin        ;get another character
```

Reset Disk (Function 0DH)

Call:

AH = 0DH

Return:

None

Comments:

Function 0DH flushes all file buffers to ensure that the internal buffer cache matches the disks in the drives. It writes out buffers that have been modified, and marks all buffers in the internal cache as free. This function request is normally used to force a known state of the system; CONTROL-C interrupt handlers should call this function.

This function does not update directory entries; you must close changed files to update their directory entries (see Function 10H, Close File).

Macro Definition:

```
reset_disk macro
           mov   ah,0DH
           int   21H
           endm
```

Example:

The following program flushes all file buffers and selects disk A.

```
begin:  reset_disk
        select_disk "A"
```

Select Disk (Function 0EH)

Call:

AH = 0EH
DL
  Logical drive number
  (0 = A, 1 = B, etc.)

Return:

AL
  Number of logical drives

Comments:

Function 0EH selects the drive specified in DL (0=A, 1=B, etc.) as the current logical drive. AL returns the number of logical drives.

.....
Note
  For future compatibility, treat the value returned in AL with care. For example, if AL returns 5, it is not safe to assume that drives A, B, C, D, and E are all valid drive designators.
.....

Macro Definition:

```
select_disk macro disk
```

```
            mov   dl,disk[-64]
            mov   ah,0EH
            int   21H
            endm
```

Example:

The following program toggles between drive A and drive B to select the current drive (in a two-drive system).

```
begin:    current_disk       ;see Function 19H
          cmp    al,00H      ;drive A: selected?
          je     select_b    ;yes, select B
          select_disk "A"    ;THIS FUNCTION
          jmp    return
select_b: select_disk "B"    ;THIS FUNCTION
```

Open File (Function 0FH)

Call:

AH = 0FH
DS:DX
  Pointer to unopened FCB

Return:

AL
  00H   = Directory entry found
  FFH   = No directory entry found

Comments:

Function 0FH opens a file. DX must contain the offset (from the segment address in DS) of an unopened File Control Block (FCB). This call searches the disk directory for the named file.

If the call finds a directory entry for the file, AL returns 0 and the FCB is filled as follows:

- If the drive code was 0 (current drive), it is changed to the actual drive used (1=A, 2=B, etc.). This lets you change the current drive without interfering with subsequent operations on this file.
- Current Block (offset 0CH) is set to 0.
- Record Size (offset 0EH) is set to the system default of 128.
- File Size (offset 0FH), Date of Last Write (offset 13H), and Time of Last Write (offset 15H) are set from the directory entry.

Before performing a sequential disk operation on the file, you must set the Current Record field (offset 1FH). Before performing a random disk operation on the file, you must set the Relative Record field (offset 20H). If the default record size (128 bytes) is not correct, set it to the correct length.

If the call doesn't find a directory entry for the file, or if the file has the hidden or system attribute, AL returns 0FFH.

Macro Definition:

```
open  macro fcb
      mov   dx,offset fcb
      mov   ah,0FH
      int   21H
      endm
```

Example:

The following program prints a file named textfile.asc that is on the disk in drive B. If a partial record is in the buffer at end-of-file, the routine that prints the partial record prints characters until it encounters an end-of-file mark (ASCII 26, or CONTROL-Z).

```
fcb            db    2,"TEXTFILEASC"
               db    26 dup (?)
buffer         db    128 dup (?)
;
begin:         set_dta  buffer       ;see Function 1AH
               open  fcb             ;THIS FUNCTION
read_line:     read_seq  fcb         ;see Function 14H
               cmp   al,02H          ;end of file?
               je    all_done        ;yes, go home
               cmp   al,00H          ;more to come?
               jg    check_more      ;no, check for partial
                                     ;record
               mov   cx,80H          ;yes, print the buffer
               xor   si,si           ;set index to 0
print_it:      print_char buffer[si] ;see Function 05H
               inc   si              ;bump index
               loop  print_it        ;print next character
               jmp   read_line       ;read another record
check_more:    cmp   al,03H          ;part. record to print?
               jne   all_done        ;no
               mov   cx,80H          ;yes, print it
               xor   si,si           ;set index to 0
find_eof:      cmp   buffer[si],26   ;end-of-file mark?
               je    all_done        ;yes
               print_char buffer[si] ;see Function 05H
               inc   si              ;bump index to next
                                     ;character
               loop  find_eof
all_done:      close fcb             ;see Function 10H
```

Close File (Function 10H)

Call:

AH = 10H
DS:DX
  Pointer to opened FCB

Return:

AL
  00H   = Directory entry found
  FFH   = No directory entry found

Comments:

Function 10H closes a file. DX must contain the offset (to the segment address in DS) of an opened FCB. This call searches the disk directory for the file named in the FCB. If it finds a directory entry for the file, it compares the location of the file with the corresponding entries in the FCB. The call then updates the directory entry, if necessary, to match the FCB, and AL returns 0.

After you change a file, you must call this function to update the directory entry. You should close any FCB (even one for a file that has not been changed) when you no longer need access to a file.

If this call doesn't find a directory entry for the file, AL returns FFH.

Macro Definition:

```
close  macro fcb
       mov   dx,offset fcb
       mov   ah,10H
       int   21H
       endm
```

Example:

The following program checks the first byte of the file named mod1.bas in drive B to see if it is FFH and, if it is, prints a message.

```
message        db   "Not saved in ASCII format",0DH,0AH,"$"
fcb            db    2,"MOD1    BAS"
               db    26  dup (?)
buffer         db    128 dup (?)
;
begin:         set_dta  buffer       ;see Function 1AH
               open  fcb             ;see Function 0FH
               read_seq  fcb         ;see Function 14H

               cmp   buffer,0FFH     ;is first byte FFH?
               jne   all_done        ;no
               display  message      ;see Function 09H
all_done:      close fcb             ;THIS FUNCTION
```

Search for First Entry (Function 11H)

Call:

AH = 11H
DS:DX
  Pointer to unopened FCB

Return:

  AL
  00H   = Directory entry found
  FFH   = No directory entry found

Comments:

Function 11H searches the disk directory for the first matching filename. DX must contain the offset (from the segment address in DS) of an unopened FCB. The filename in the FCB can include wildcard characters. To search for hidden or system files, DX must point to the first byte of an extended FCB prefix.

If this call does not find a directory entry for the filename in the FCB, AL returns FFH.

But if the call does find a directory entry for the filename in the FCB, AL returns 0 and the call creates an unopened FCB of the same type (normal or extended) at the Disk Transfer Address as follows:

1. If the search FCB was normal, the first byte at the Disk Transfer Address is set to the drive number used in the search (1=A, 2=B, etc.) and the next 32 bytes contain the directory entry.

2. If the search FCB was extended, the first byte at the Disk Transfer Address is set to FFH, the next 5 bytes are set to 00H, and the following byte is set to the value of the attribute byte in the search FCB. The remaining 33 bytes are the same as the result of the normal FCB (drive number and 32 bytes of directory entry).

If you use Function 12H (Search for Next Entry) to continue searching for matching filenames, you must not alter or open the original FCB at DS:DX.

The attribute field is the last byte of the extended FCB fields that precede the FCB (see earlier in this chapter). If the attribute field is zero, Function 11H searches only normal file entries. It does not search directory entries for hidden files, system files, volume label, and subdirectories.

If the attribute field is hidden file, system file, or subdirectory entry (02H, 04H, or 10H), or any combination of those values, this call also searches all normal file entries. To search all directory entries except the volume label, set the attribute byte to 16H (hidden file and system file and directory entry).

If the attribute field is Volume ID (08H), the call searches only the volume label entry.

Macro Definition:

```
search_first  macro fcb
              mov   dx,offset fcb
              mov   ah,11H
              int   21H
              endm
```

Example:

The following program verifies the existence of a file named report.asm on the disk in drive B.

```
yes         db   "FILE EXISTS.$"
no          db   "FILE DOES NOT EXIST.$"
crlf        db    0DH,0AH,"$"
fcb         db    2,"REPORT  *ASM"
```

```
           db    26 dup (?)
buffer     db    128 dup (?)
;
begin:     set_dta  buffer           ;see Function 1AH
           search_first fcb          ;THIS FUNCTION
           cmp      al,0FFH          ;directory entry found?
           je       not_there        ;no
           display  yes              ;see Function 09H
           jmp      continue
not_there: display  no               ;see Function 09H
continue:  display  crlf             ;see Function 09H
```

Search for Next Entry (Function 12H)

Call:

AH = 12H
DS:DX
  Pointer to unopened FCB

Return:

AL
  00H   = Directory entry found
  FFH   = No directory entry found

Comments:

After you use Function 11H (Search for First Entry), you can use Function 12H to find any additional directory entries that match a filename (containing wildcard characters). Function 12H searches the disk directory for the next matching name. DX must contain the offset (from the segment address in DS) of an FCB specified in a previous call to Function 11H. To search for hidden or system files, DX must point to the first byte of an extended FCB prefix-one that includes the appropriate attribute value.

If the call does not find a directory entry for the filename in the FCB, AL returns FFH.

But if the call does find a directory entry for the filename in the FCB, AL returns 0 and the call creates an unopened FCB of the same type (normal or extended) at the Disk Transfer Address (see Function 11H for a description of how the unopened FCB is formed).

Macro Definition:

```
search_next  macro fcb
             mov   dx,offset fcb
             mov   ah,12H
             int   21H
             endm
```

Example:

The following program displays the number of files on the disk in drive B.

```
message     db   "No files",0DH,0AH,"$"
```

```
files       db    0
fcb         db    2,"???????????"
            db    26  dup (?)
buffer      db    128 dup (?)
;
begin:      set_dta  buffer          ;see Function 1AH
            search_first  fcb        ;see Function 11H
            cmp  al,0FFH             ;directory entry found?
            je   all_done            ;no, no files on disk
            inc  files               ;yes, increment file
                                     ;counter
search_dir: search_next  fcb         ;THIS FUNCTION
            cmp  al,0FFH             ;directory entry found?
            je   done                ;no
            inc  files               ;yes, increment file
                                     ;counter
            jmp  search_dir          ;check again
done:       convert files,10,message ;see end of chapter
all_done:   display  message         ;see Function 09H
```

Delete File (Function 13H)

Call:

AH = 13H
DS:DX
  Pointer to unopened FCB

Return:

```
  AL
  00H     = Directory entry found
  FFH     = No directory entry found
```

Comments:

Function 13H deletes a file. DX must contain the offset (from the segment address in DS) of an unopened FCB. This call searches the directory for a matching filename. The filename in the FCB can contain wildcard characters.

If the call does not find a matching directory entry, AL returns FFH.

But if the call does find a matching directory entry, AL returns 0 and the call deletes the entry from the directory. If the filename contains a wildcard character, the call will delete all files which match.

Do not delete open files.

Macro Definition:

```
delete  macro  fcb
        mov    dx,offset fcb
        mov    ah,13H
        int    21H
        endm
```

Example:

The following program deletes each file on the disk in drive B that was last written before December 31, 1982.

```
year            dw    1982
month           db    12
day             db    31
files           db    0
message         db   "No files deleted.",0DH,0AH,"$"
fcb             db    2,"???????????"
                db    26 dup  (?)
buffer          db    128 dup (?)
;
begin:          set_dta  buffer      ;see Function 1AH
                search_first fcb     ;see Function 11H
                cmp   al,0FFH        ;directory entry found?
                jne   compare        ;yes
                jmp   all_done       ;no, no files on disk
compare:        convert_date buffer  ;see end of chapter
                cmp  cx,year         ;next several lines
                jg   next            ;check date in directory
                cmp  dl,month        ;entry against date
                jg   next            ;above & check next file
                cmp  dh,day          ;if date in directory
                jge  next            ;entry isn't earlier.
                delete  buffer       ;THIS FUNCTION
                inc  files           ;bump deleted-files
                                     ;counter
next:           search_next fcb      ;see Function 12H
                cmp  al,00H          ;directory entry found?
                je   compare         ;yes, check date
                cmp  files,0         ;any files deleted?
                je   all_done        ;no, display No files
                                     ;message.
                convert files,10,message ;see end of chapter
all_done:       display message      ;see Function 09H
```

Sequential Read (Function 14H)

Call:

AH = 14H
DS:DX
  Pointer to opened FCB

Return:

AL
  00H = Read completed successfully
  01H = EOF
  02H = DTA too small
  03H = EOF, partial record

Comments:

Function 14H reads a record from a specified file. DX must contain the offset (from the segment address in DS) of an opened FCB. This call loads the record pointed to by the Current Block field (offset 0CH) and Current Record (offset 1FH) field at the Disk Transfer Address, then increments the Current Block and Current Record fields.

The length of the record is taken from the Record Size field (offset 0EH) of the FCB.

AL returns a code that describes the processing:

Code	Meaning
0	Read completed successfully
1	End-of-file; no data in the record
2	Not enough room at the Disk Transfer Address to read one record; read canceled
3	End-of-file; a partial record was read and padded to the record length with zeros

Macro Definition:

```
read_seq  macro fcb
          mov   dx,offset fcb
          mov   ah,14H
          int   21H
          endm
```

Example:

The following program displays a file named textfile.asc that is on the disk in drive B; its function is similar to the MS-DOS type command. If a partial record is in the buffer at end-of-file, the routine that displays the partial record displays characters until it encounters an end-of-file mark (ASCII 26, or CONTROL-Z).

```
fcb            db    2,"TEXTFILEASC"
               db    26  dup (?)
buffer         db    128 dup (?),"$"
;
begin:         set_dta  buffer    ;see Function 1AH
               open  fcb          ;see Function 0FH
read_line:     read_seq  fcb      ;THIS FUNCTION
               cmp   al,02H       ;DTA too small?
               je    all_done     ;yes
               cmp   al,00H       ;end-of-file?
               jg    check_more   ;yes
               display  buffer    ;see Function 09H
               jmp   read_line    ;get another record
check_more:    cmp   al,03H       ;partial record in buffer?
               jne   all_done     ;no, go home
               xor   si,si        ;set index to 0
find_eof:      cmp   buffer[si],26 ;is character EOF?
               je    all_done     ;yes, no more to display
               display_char buffer[si]  ;see Function 02H
               inc   si           ;bump index
               jmp   find_eof     ;check next character
all_done:      close fcb          ;see Function 10H
```

Sequential Write (Function 15H)

Call:

```
AH = 15H
DS:DX
  Pointer to opened FCB


Return:

AL
  00H = Write completed successfully
  01H = Disk full
  02H = DTA too small
```

Function 15H writes a record to a specified file. DX must contain the offset (from the segment address in DS) of an opened FCB. This call writes the record pointed to by the Current Block field (offset 0CH) and Current Record field (offset 1FH) at the Disk Transfer Address, then increments the Current Block and Current Record fields.

The record size is taken from the value of the Record Size field (offset 0EH) of the FCB. If the record size is less than a sector, the call writes the data at the Disk Transfer Address to an MS-DOS buffer; MS-DOS writes the buffer to disk when it contains a full sector of data, when the file is closed, or when Function 0DH (Reset Disk) is issued.

AL returns a code that describes the processing:

Code	Meaning
0	Write completed successfully
1	Disk full; write canceled
2	Not enough room at the Disk Transfer Address to write one record; write canceled

```
Macro Definition:

write_seq  macro fcb
           mov   dx,offset fcb
           mov   ah,15H
           int   21H
           endm


Example:
```

The following program creates a file named dir.tmp on the disk in drive B, containing the disk number (0=A, 1=B, etc.) and filename from each directory entry on the disk.

```
record_size    equ   0EH           ;offset of Record Size
;                                  field in FCB
fcb1           db    2,"DIR     TMP"
               db    26 dup (?)
fcb2           db    2,"???????????"
               db    26 dup (?)
buffer         db    128 dup (?)
;
begin:      set_dta      buffer     ;see Function 1AH
            search_first fcb2       ;see Function 11H
            cmp          al,0FFH    ;directory entry found?
            je           all_done   ;no, no files on disk
            create       fcb1       ;see Function 16H
```

```
            mov         fcb1[record_size],12
                                    ;set record size to 12
write_it:   write_seq   fcb1        ;THIS FUNCTION
            cmp         al,0        ;write successful?
            jne         all_done    ;no, go home
            search_next fcb2        ;see Function 12H
            cmp         al,FFH      ;directory entry found?
            je          all_done    ;no, go home
            jmp         write_it    ;yes, write the record
all_done:   close       fcb1        ;see Function 10H
```

Create File (Function 16H)

Call:

AH = 16H
DS:DX
  Pointer to unopened FCB

Return:

AL
  00H   = Empty directory found
  FFH   = No empty directory available

Function 16H creates a file. DX must contain the offset(from the segment address in DS) of an unopened FCB. MS-DOS searches the directory for an entry that matches the specified filename or, if there is no matching entry, an empty entry.

If MS-DOS finds a matching entry, it opens the file and sets the length to zero (in other words, if you try to create a file that already exists, MS-DOS erases it and creates a new, empty file). If MS-DOS doesn't find a matching entry but does find an empty directory entry, it opens the file and sets its length to zero. In either case, the call creates the file, and AL returns 0. If MS-DOS doesn't find a matching entry and there is no empty entry, the call doesn't create the file, and AL returns FFH.

You can assign an attribute to the file by using an extended FCB with the attribute byte set to the appropriate value (see Extended FCB in Section 1.9.1).

Macro Definition:

```
create  macro fcb
        mov   dx,offset fcb
        mov   ah,16H
        int   21H
        endm
```

Example:

The following program creates a file named dir.tmp on the disk in drive B, containing the disk number (0 = A, 1 = B, etc.) and filename from each directory entry on the disk.

```
record_size    equ   0EH          ;offset of Record Size
;                                  field of FCB
fcb1           db    2,"DIR     TMP"
```

```
                db    26  dup (?)
fcb2            db    2,"???????????"
                db    26  dup (?)
buffer          db    128 dup (?)
;
begin:          set_dta   buffer     ;see Function 1AH
                search_first  fcb2   ;see Function 11H
                cmp       al,0FFH    ;directory entry found?
                je        all_done   ;no, no files on disk
                create    fcb1       ;THIS FUNCTION
                mov       fcb1[record_size],12
                                     ;set record size to 12
write_it:       write_seq fcb1       ;see Function 15H
                cmp       al,0       ;write successful
                jne       all_done   ;no, go home
                search_next  fcb2    ;see Function 12H
                cmp       al,FFH     ;directory entry found?
                je        all_done   ;no, go home
                jmp       write_it   ;yes, write the record
all_done:       close     fcb1       ;see Function 10H
```

Rename File (Function 17H)

Call:

AH = 17H
DS:DX
  Pointer to modified FCB

Return:

AL
  00H   = Directory entry found
  FFH   = No directory entry found
            or destination already exists

Comments:

Function 17H changes the name of an existing file. DX must contain the offset (from the segment address in DS) of an FCB with the drive number and filename filled in, followed by a second filename at offset 11H. DOS searches the disk directory for an entry that matches the first filename. This filename can contain wildcard characters.

If MS-DOS finds a matching directory entry and there is no directory entry that matches the second filename, it changes the filename in the directory entry to match the second filename in the modified FCB. AL then returns zero. If the second filename does contain a wildcard character, this call does not change the corresponding characters in the filename of the directory entry.

You cannot use this function request to rename a hidden file, a system file, or a subdirectory. If MS-DOS does not find a matching directory entry or if it finds an entry for the second filename, AL returns FFH.

Macro Definition:

```
rename macro fcb,newname
       mov   dx,offset fcb
```

```
        mov   ah,17H
        int   21H
        endm
```

Example:

The following program prompts for the name of a file and a new name; it then renames the file.

```
fcb               db    37 dup (?)
prompt1           db   "Filename: $"
prompt2           db   "New name: $"
reply             db    15 dup(?)
crlf              db    0DH,0AH,"$"
;
begin:            display  prompt1       ;see Function 09H
                  get_string  15,reply   ;see Function 0AH
                  display  crlf          ;see Function 09H
                  parse    reply[2],fcb  ;see Function 29H
                  display  prompt2       ;see Function 09H
                  get_string  15,reply   ;see Function 0AH
                  display  crlf          ;see Function 09H
                  parse    reply[2],fcb[16]
                                         ;see Function 29H
                  rename   fcb           ;THIS FUNCTION
```

Get Current Disk (Function 19H)

Call:

AH = 19H

Return:

AL
  Currently selected drive
  (0 = A, 1 = B, etc.)

Comments:

Function 19H returns the current drive in AL (0=A, 1=B, etc.).

Macro Definition:

```
current_disk  macro
              mov   ah,19H
              int   21H
              endm
```

Example:

The following program displays the default drive in a two-drive system.

```
message    db  "Current disk is $"
crlf       db   0DH,OAH,"$"
;
```

```
begin:     display  message         ;see Function 09H
           current_disk             ;THIS FUNCTION
           cmp      al,00H          ;is it disk A?
           jne      disk_b          ;no, it's disk B:
           display_char "A"         ;see Function 02H
           jmp      all_done
disk_b:    display_char "B"         ;see Function 02H
all_done:  display  crlf            ;see Function 09H
```

Set Disk Transfer Address (Function 1AH)set disk transfer address

Call:

AH = 1AH
DS:DX
 Disk Transfer Address

Return:

None

Comments:

Function 1AH sets the Disk Transfer Address. DX must contain the offset (from the segment address in DS) of the Disk Transfer Address. Disk transfers cannot wrap around from the end of the segment to the beginning, nor can they overflow into another segment.

If you do not set the Disk Transfer Address, MS-DOS defaults to offset 80H in the Program Segment Prefix. You can check the current Disk Transfer Address with Function 2FH (Get Disk Transfer Address).

Macro Definition:

```
set_dta  macro  buffer
         mov    dx,offset buffer
         mov    ah,1AH
         int    21H
         endm
```

Example:

The following program prompts for a letter, converts it to its alphabetic sequence (A=1, B=2, etc.), then reads and displays the corresponding record from a file named alphabet.dat that is on the disk in drive B. The file contains 26 records, each 28 bytes long.

```
record_size     equ   0EH      ;offset of Record Size
                              ;field of FCB
relative_record equ   21H      ;offset of Relative Record
;                             field of FCB
fcb           db    2,"ALPHABETDAT"
              db    26  dup (?)
buffer        db    28 dup(?),"$"
prompt        db   "Enter letter: $"
crlf          db    0DH,0AH,"$"
;
begin:        set_dta  buffer       ;THIS FUNCTION
```

```
              open     fcb          ;see Function 0FH
              mov      fcb[record_size],28 ;set record size
get_char:     display  prompt       ;see Function 09H
              read_kbd_and_echo     ;see Function 01H
              cmp      al,0DH       ;just a CR?
              je       all_done     ;yes, go home
              sub      al,41H       ;convert ASCII
                                    ;code to record #
              mov      fcb[relative_record],al
                                    ;set relative record
              display  crlf         ;see Function 09H
              read_ran fcb          ;see Function 21H
              display  buffer       ;see Function 09H
              display  crlf         ;see Function 09H
              jmp      get_char     ;get another character
all_done:     close    fcb          ;see Function 10H
```

Get Default Drive Data (Function 1BH)

Call:

AH = 1BH

Return:

AL
   Sectors per cluster
CX
   Bytes per sector
DX
   Clusters per drive
DS:BX
   Pointer to FAT ID byte

Comments

Function 1BH retrieves data about the disk in the default drive. The data returns in the following registers:

Register	Contents
AL	Number of sectors in a cluster (allocation unit)
CX	Number of bytes in a sector
DX	Number of clusters on the disk

BX returns the offset (to the segment address in DS) of the first byte of the File Allocation Table (FAT), which identifies the type of disk in the drive:

Value	Type of Drive
FF	Double-sided disk, 8 sectors per track, 40 tracks per side
FE	Single-sided disk, 8 sectors per track, 40 tracks per side
FD	Double-sided disk, 9 sectors per track, 40 tracks per side
FC	Single-sided disk, 9 sectors per track, 40 tracks per side
F9	Double-sided disk, 15 sectors per track, 40 tracks per side
F9	Double-sided disk, 9 sectors per track, 80 tracks per side
F8	Fixed disk

This call is similar to Function 36H (Get Disk Free Space), except that it

returns the address of the FAT ID byte in BX instead of the number of available clusters. It is also similar to Function 1CH (Get Drive Data), except that it returns data on the disk in the default drive instead of on the disk in a specified drive. For a description of how MS-DOS stores data on a disk, including a description of the File Allocation Table, see Chapter 3, "MS-DOS Technical Information."

.....
Warning
  The FAT ID byte is no longer adequate to identify the type of drive being used. See Chapter 2, "MS-DOS Device Drivers," for more details.
.....

Macro Definition:

```
def_drive_data  macro
                push   ds
                mov    ah,1BH
                int    21H
                mov    al,byte ptr[bx]
                pop    ds
                endm
```

Example:

The following program displays a message that tells whether the default drive is a disk or a fixed disk drive.

```
stdout      equ         1
;
msg         db          "Default drive is "
dskt        db          "disk."
fixed       db          "fixed."
crlf        db          ODH,OAH
;
begin:      write_handle stdout,msg,17      ;display message
            jc           write_error        ;routine not shown
            def_drive_data                  ;THIS FUNCTION
            cmp          byte ptr [bx],0F8H ;check FAT ID byte
            jne          disk           ;it's a disk
            write_handle stdout,fixed,6     ;see Function 40H
            jc           write_error        ;see Function 40H
            jmp short    all_done           ;clean up & go home
disk:   write_handle stdout,dskt,9          ;see Function 40H
all_done:   write_handle stdout,crlf,2  ;see Function 40H
            jc           write_error        ;routine not shown
```

Get Drive Data (Function 1CH)

Call:

AH = 1CH
DL
   Drive (0=default, 1=A, etc.)

Return:

AL
   0FFH if drive number is invalid;

   otherwise, sectors per cluster
CX
   Bytes per sector
DX
   Clusters per drive
DS:BX
   Pointer to FAT ID byte

Comments:

Function 1CH retrieves data about the disk in the specified drive. DL must contain the drive number (0=default, 1=A, etc.). The data returns in the following registers:

Register	Contents
AL	Number of sectors in a cluster (allocation unit)
CX	Number of bytes in a sector
DX	Number of clusters on the disk

BX returns the offset (to the segment address in DS) of the first byte of the File Allocation Table (FAT), which identifies the type of disk in the drive:

Value	Type of Drive
FF	Double-sided disk, 8 sectors per track, 40 tracks per side
FE	Single-sided disk, 8 sectors per track, 40 tracks per side
FD	Double-sided disk, 9 sectors per track, 40 tracks per side
FC	Single-sided disk, 9 sectors per track, 40 tracks per side
F9	Double-sided disk, 15 sectors per track, 40 tracks per side
F9	Double-sided disk, 9 sectors per track, 80 tracks per side
F8	Fixed disk

If the drive number in DL is invalid, AL returns 0FFH.

Warning
  The FAT ID byte is no longer adequate to identify the type of drive being used. See Chapter 2, "MS-DOS Device Drivers" for more details.

This call is similar to Function 36H (Get Disk Free Space), except that it returns the address of the FAT ID byte in BX instead of the number of available clusters. It is also similar to Function 1BH (Get Default Drive Data), except that it returns data on the disk in the drive specified in DL instead of the disk in the default drive. For a description of how MS-DOS stores data on a disk, including a description of the File Allocation Table, see Chapter 3, "MS-DOS Technical Information."

Macro Definition:

```
drive_data  macro  drive
            push   ds
            mov    dl,drive
            mov    ah,1BH
            int    21H
            mov    al, byte ptr[bx]
            pop    ds
            endm
```

Example:

The following program displays a message that tells whether drive B is a disk or a fixed disk drive.

```
stdout      equ          1
:
msg         db           "Drive B is "
dskt        db           "disk."
fixed       db           "fixed."
crlf        db           ODH,OAH
;
begin:      write_handle stdout,msg,11      ;display message
            jc           write_error        ;routine not shown
            drive_data   2                  ;THIS FUNCTION
            cmp          byte ptr [bx],0F8H ;check FAT ID byte
            jne          disk           ;it's a disk
            write_handle stdout,fixed,6     ;see Function 40H
            jc           write_error        ;routine not shown
            jmp          all_done           ;clean up & go home
disk:   write_handle stdout,dskt,9      ;see Function 40H
all_done:   write_handle stdout,crlf,2      ;see Function 40H
            jc           write_error        ;routine not shown
```

Random Read (Function 21H)

Call:

AH = 21H
DS:DX
  Pointer to opened FCB

Return:

AL
  0 = Read completed successfully
  1 = End of file, record empty
  2 = DTA too small
  3 = End of file, partial record

Comments:

Function 21H reads (into the Disk Transfer Address) the record pointed to by the Relative Record field (offset 20H) of the FCB. DX must contain the offset (from the segment address in DS) of an opened FCB. The Current Block field (offset 0CH) and Current Record field (offset 1FH) are set to agree with the Relative Record field (offset 20H). The record is then loaded at the Disk Transfer Address. The record length is taken from the Record Size field (offset 0EH) of the FCB.

AL returns a code that describes the processing:

Code	Meaning
0	Read completed successfully
1	End-of-file; no data in the record
2	Not enough room at the Disk Transfer Address to read one record; read canceled

3 End-of-file; a partial record was read and padded to the record length with zeros

Macro Definition:

```
read_ran  macro  fcb
          mov    dx,offset fcb
          mov    ah,21H
          int    21H
          endm
```

Example:

The following program prompts for a letter, converts it to its alphabetic sequence (A = 1, B = 2, etc.), then reads and displays the corresponding record from a file named alphabet.dat that is on the disk in drive B. The file contains 26 records, each 28 bytes long.

```
record_size     equ   0EH      ;offset of Record Size
                              ;field of FCB
relative_record equ   21H      ;offset of Relative Record
;                             field of FCB
fcb           db    2,"ALPHABETDAT"
              db    26  dup (?)
buffer        db    28 dup(?),"$"
prompt        db   "Enter letter: $"
crlf          db    0DH,0AH,"$"
;
begin:        set_dta  buffer            ;see Function 1AH
              open     fcb               ;see Function 0FH
              mov      fcb[record_size],28 ;set record size
get_char:     display  prompt            ;see Function 09H
              read_kbd_and_echo          ;see Function 01H
              cmp      al,0DH            ;just a CR?
              je       all_done          ;yes, go home
              sub      al,41H            ;convert ASCII code
                                         ;to record #
              mov      fcb[relative_record],al ;set relative
                                         ;record
              display  crlf              ;see Function 09H
              read_ran fcb               ;THIS FUNCTION
              display  buffer            ;see Function 09H
              display  crlf              ;see Function 09H
              jmp      get_char          ;get another char.
all_done:     close    fcb               ;see Function 10H
```

Random Write (Function 22H)

Call:

AH = 22H
DS:DX
  Pointer to opened FCB

Return:

AL
  00H = Write completed successfully

```
  01H = Disk full
  02H = DTA too small
```

Comments:

Function 22H writes (from the Disk Transfer Address) the record pointed to by the Relative Record field (offset 20H) of the FCB. DX must contain the offset from the segment address in DS of an opened FCB. The Current Block (offset 0CH) and Current Record (offset 1FH) fields are set to agree with the Relative Record field (offset 20H). This record is then written from the Disk Transfer Address.

The record length is taken from the Record Size field (offset 0EH) of the FCB. If the record size is less than a sector, the data at the Disk Transfer Address is written to a buffer, the buffer is written to disk when it contains a full sector of data; or when a program closes the file, or when it issues Function 0DH (Reset Disk).

AL returns a code that describes the processing:

Code	Meaning
0	Write completed successfully
1	Disk is full
2	Not enough room at the Disk Transfer Address to write one record; write canceled

Macro Definition:

```
write_ran  macro  fcb
           mov    dx,offset fcb
           mov    ah,22H
           int    21H
           endm
```

Example:

The following program prompts for a letter, converts it to its alphabetic sequence (A = 1, B = 2, etc.), then reads and displays the corresponding record from a file named alphabet.dat that is on the disk in drive B. After displaying the record, it prompts you to enter a changed record. If you type a new record, it is written to the file, but if you just press the RETURN key, the record is not replaced. The file contains 26 records, each 28 bytes long.

```
record_size     equ   0EH      ;offset of Record Size
                               ;field of FCB
relative_record equ   21H      ;offset of Relative Record
;                              field of FCB
fcb        db    2,"ALPHABETDAT"
           db    26  dup (?)
buffer     db    28 dup(?),0DH,0AH,"$"
prompt1    db   "Enter letter: $"
prompt2    db   "New record (RETURN for no change): $"
crlf       db    0DH,0AH,"$"
reply      db    28 dup (32)
blanks     db    26 dup (32)
;
begin:     set_dta  buffer            ;see Function 1AH
```

```
            open     fcb                ;see Function 0FH
            mov      fcb[record_size],28 ;set record size
get_char:   display  prompt1            ;see Function 09H
            read_kbd_and_echo           ;see Function 01H
            cmp      al,0DH             ;just a carriage return?
            je       all_done           ;yes, go home
            sub      al,41H             ;convert ASCII
                                        ;code to record #
            mov      fcb[relative_record],al
                                        ;set relative record
            display  crlf               ;see Function 09H
            read_ran fcb                ;THIS FUNCTION
            display  buffer             ;see Function 09H
            display  crlf               ;see Function 09H
            display  prompt2            ;see Function 09H
            get_string 27,reply         ;see Function 0AH
            display  crlf               ;see Function 09H
            cmp      reply[1],0         ;was anything typed
                                        ;besides CR?
            je       get_char           ;no
                                        ;get another char.
            xor      bx,bx              ;to load a byte
            mov      bl,reply[1]        ;use reply length as
                                        ;counter
            move_string blanks,buffer,26 ;see chapter end
            move_string reply[2],buffer,bx ;see chapter end
            write_ran fcb               ;THIS FUNCTION
            jmp      get_char           ;get another character
all_done:   close    fcb                ;see Function 10H
```

Get File Size (Function 23H)

Call:

AH = 23H
DS:DX
  Pointer to unopened FCB

Return:

AL
  00H = Directory entry found
  FFH = No directory entry found

Comments:

Function 23H returns the size of a specified file. DX must contain the offset (from the segment address in DS) of an unopened FCB.

If there is a directory entry that matches the specified file, MS-DOS divides the File Size field (offset 1CH) of the directory entry by the Record Size field (offset 0EH) of the FCB, puts the result in the Relative Record field (offset 20H) of the FCB, and returns 00 in AL.

You must set the Record Size field of the FCB to the correct value before calling this function. If the Record Size field is not an even divisor of the File Size field, the value set in the Relative Record field is rounded up, yielding a value larger than the actual number of records.

If this call does not find a matching directory, AL returns FFH.

Macro Definition:

```
file_size  macro  fcb
           mov    dx,offset fcb
           mov    ah,23H
           int    21H
           endm
```

Example:

The following program prompts for the name of a file, opens the file to fill in the Record Size field of the FCB, issues a File Size system call, and displays the record length and number of records.

```
fcb           db      37 dup  (?)
prompt        db     "File name: $"
msg1          db     "Record length:     ",0DH,0AH,"$"
msg2          db     "Records:      ",0DH,0AH,"$"
crlf          db      0DH,0AH,"$"
reply         db      17 dup(?)
;
begin:        display prompt            ;see Function 09H
              get_string 17,reply       ;see Function 0AH
              cmp     reply[1],0        ;just a CR?
              jne     get_length        ;no, keep going
              jmp     all_done          ;yes, go home
get_length:   display crlf              ;see Function 09H
              parse   reply[2],fcb      ;see Function 29H
              open    fcb               ;see Function 0FH
              file_size fcb             ;THIS FUNCTION
              mov     ax,word ptr fcb[33] ;get record length
              convert ax,10,msg2[9]     ;see end of chapter
              mov     ax,word ptr fcb[14] ; get record number
              convert ax,10,msg1[15]    ;see end of chapter
              display msg1              ;see Function 09H
              display msg2              ;see Function 09H
all_done:     close   fcb               ;see Function 10H
```

Set Relative Record (Function 24H)

Call:

AH = 24H
DS:DX
  Pointer to opened FCB

Return:

None

Comments:

Function 24H sets the Relative Record field (offset 20H) to the file address specified by the Current Block field (offset 0CH) and Current Record field (offset 1FH). DX must contain the offset (from the segment address in DS) of an opened FCB. You use this call to set the file pointer before a Random Read or Write (Functions 21H, 22H, 27H, or 28H).

Macro Definition:

```
set_relative_record  macro  fcb
                     mov    dx,offset fcb
                     mov    ah,24H
                     int    21H
                     endm
```

Example:

The following program copies a file using the Random Block Read and Random Block Write system calls. It speeds the copy by setting the record length equal to the file size and the record count to 1, and by using a buffer of 32K bytes. It positions the file pointer by setting the Current Record field (offset 1FH) to 1 and using Function 24H (Set Relative Record) to make the Relative Record field (offset 20H) point to the same record that the combination of the Current Block field (offset 0CH) and Current Record field (offset 1FH) points to.

```
current_record  equ   20H        ;offset of Current Record
                                  ;field of FCB
fil_size        equ   10H        ;offset of File Size
;                                 field of FCB
fcb       db      37 dup (?)
filename  db      17 dup(?)
prompt1   db     "File to copy: $"  ;see Function 09H for
prompt2   db     "Name of copy: $"  ;explanation of $
crlf      db      0DH,0AH,"$"
file_length  dw   ?
buffer    db      32767 dup(?)
;
begin:    set_dta  buffer                    ;see Function 1AH
          display  prompt1                   ;see Function 09H
          get_string  15,filename            ;see Function 0AH
          display  crlf                      ;see Function 09H
          parse    filename[2],fcb           ;see Function 29H
          open     fcb                       ;see Function 0FH
          mov      fcb[current_record],0     ;set Current Record field
          set_relative_record  fcb           ;THIS FUNCTION
          mov      ax,word ptr fcb[fil_size] ;get file size
          mov      file_length,ax            ;save it for ran_block_write
          ran_block_read  fcb,1,ax           ;see Function 27H
          display  prompt2                   ;see Function 09H
          get_string  15,filename            ;see Function 0AH
          display  crlf                      ;see Function 09H
          parse    filename[2],fcb           ;see Function 29H
          create   fcb                       ;see Function 16H
          mov      fcb[current_record],0     ;set Current Record field
          set_relative_record  fcb           ;THIS FUNCTION
          mov      ax,file_length            ;get original file
          ran_block_write  fcb,1,ax          ;see Function 28H
          close    fcb                       ;see Function 10H
```

Set Interrupt Vector (Function 25H)

Call:

AH = 25H
AL

  Interrupt number
DS:DX
  Pointer to interrupt-handling
  routine

Return:

None

Comments:

Function 25H sets the address in the interrupt vector table for the specified interrupt.

AL must contain the number of the interrupt. DX must contain the offset (to the segment address in DS) of the interrupt-handling routine.

To avoid compatibility problems, programs should never set an interrupt vector directly and should never use Interrupt 25H to read directly from memory. To get a vector, use Function 35H (Get Interrupt Vector), and to set a vector, use Function 25H, unless your program must be compatible with MS-DOS versions earlier than 2.0.

Macro Definition:

```
set_vector  macro  interrupt,handler_start
            mov    al,interrupt
            mov    dx,offset handler_start
            mov    ah,25H
            endm
```

Example:

Because interrupts tend to be machine-specific, no example is shown.

Create New PSP (Function 26H)

Call:

AH = 26H
DX
  Segment address of new PSP

Return:

None

Comments:

This function request has been superseded. Use Function 4BH (Load and Execute Program) to run a child process, unless your program must be compatible with MS-DOS versions earlier than 2.0.

Function 26H creates a new Program Segment Prefix. DX must contain the segment address where the new PSP is to be created.

Macro Definition:

```
create_psp  macro  seg_addr
            mov    dx,seg_addr
            mov    ah,26H
            endm
```

Example:

Because Function 4BH (Load and Execute Program) and 4B03H (Load Overlay) have superseded this function request, no example is shown.

Random Block Read (Function 27H)

Call:

```
AH = 27H
DS:DX
  Pointer to opened FCB
CX
  Number of blocks to read
```

Return:

```
AL
  0 = Read completed successfully
  1 = End of file, empty record
  2 = DTA too small
  3 = End of file, partial record
CX
  Number of blocks read
```

Comments:

Function 27H reads one or more records from a specified file to the Disk Transfer Address. DX must contain the offset (to the segment address in DS) of an opened FCB. CX must contain the number of records to read. Reading starts at the record specified by the Relative Record field (offset 20H); you must set this field with Function 24H (Set Relative Record) before calling this function.

DOS calculates the number of bytes to read by multiplying the value in CX by the Record Size field (offset 0EH) of the FCB.

CX returns the number of records read. The Current Block field (offset 0CH), Current Record field (offset 1FH), and Relative Record field (offset 20H) are set to address the next record.

If you call this function with CX=0, no records are read.

AL returns a code that describes the processing:

Code	Meaning
0	Read completed successfully
1	End-of-file; no data in the record

2 Not enough room at the Disk Transfer Address to read one record; read canceled

3 End-of-file; a partial record was read and padded to the record length with zeros

Macro Definition:

```
ran_block_read  macro  fcb,count,rec_size
                mov    dx,offset fcb
                mov    cx,count
                mov    word ptr fcb[14],rec_size
                mov    ah,27H
                int    21H
                endm
```

Example:

The following program copies a file by using Function 27H (Random Block Read). This program speeds the copy process by specifying a record count of 1 and a record length equal to the file size, and by using a buffer of 32K bytes; the file is read as a single record (compare to the sample program for Function 28H that specifies a record length of 1 and a record count equal to the file size).

```
current_record  equ  20H  ;offset of Current Record field
fil_size        equ  10H  ;offset of File Size field
;
fcb       db      37 dup (?)
filename  db      17 dup(?)
prompt1   db     "File to copy: $"         ;see Function 09H for
prompt2   db     "Name of copy: $"         ;explanation of $
crlf      db      0DH,0AH,"$"
file_length  dw   ?
buffer    db      32767 dup(?)
;
begin:    set_dta    buffer                ;see Function 1AH
          display    prompt1               ;see Function 09H
          get_string 15,filename           ;see Function 0AH
          display    crlf                  ;see Function 09H
          parse      filename[2],fcb       ;see Function 29H
          open       fcb                   ;see Function 0FH
          mov        fcb[current_record],0 ;set Current Record field
          set_relative_record fcb          ;see Function 24H
          mov        ax, word ptr fcb[fil_size]
                                           ;get file size
          mov        file_length,ax        ;save it
          ran_block_read  fcb,1,ax         ;THIS FUNCTION
          display    prompt2               ;see Function 09H
          get_string 15,filename           ;see Function 0AH
          display    crlf                  ;see Function 09H
          parse      filename[2],fcb       ;see Function 29H
          create     fcb                   ;see Function 16H
          mov        fcb[current_record],0 ;set current Record field
          set_relative_record fcb          ;see Function 24H
          ran_block_write  fcb,1,ax        ;see Function 28H
          close      fcb                   ;see Function 10H
```

Random Block Write (Function 28H)

Call:

AH = 28H
DS:DX
  Pointer to opened FCB
CX
  Number of blocks to write
  (0 = set File Size field)

Return:

AL
  00H = Write completed successfully
  01H = Disk full
  02H = End of segment
CX
  Number of blocks written

Comments:

Function 28H writes one or more records to a specified file from the Disk Transfer Address. DX must contain the offset (to the segment address in DS) of an opened FCB; CX must contain either the number of records to write or 0.

If CX is not 0, the specified number of records is written to the file, starting at the record specified in the Relative Record field (offset 20H) of the FCB. If CX is 0, no records are written, but MS-DOS sets the File Size field (offset 1CH) of the directory entry to the value in the Relative Record field (offset 20H) of the FCB. To satisfy this new file size, disk allocation units are allocated or released, as required.

MS-DOS calculates the number of bytes to write by multiplying the value in CX by the Record Size field (offset 0EH) of the FCB. CX returns the number of records written; the Current Block field (offset 0CH), Current Record field (offset 1FH), and Relative Record (offset 20H) field are set to address the next record.

AL returns a code that describes the processing:

Code	Meaning
0	Write completed successfully
1	Disk full. No records written
2	Not enough room at the Disk Transfer Address to write one record; write canceled

Macro Definition:

```
ran_block_write  macro  fcb,count,rec_size
                 mov    dx,offset fcb
                 mov    cx,count
                 mov    word ptr fcb[14],rec_size
                 mov    ah,28H
                 int    21H
                 endm
```

Example:

The following program copies a file using Function 27H (Random Block Read) and Function 28H (Random Block Write). This program speeds the copy process by specifying a record count equal to the file size and a record length of 1, and by using a buffer of 32K bytes; the file is copied quickly with one disk access each to read and write (compare to the sample program of Function 27H, which specifies a record count of 1 and a record length equal to file size).

```
current_record  equ  20H   ;offset of Current Record field
fil_size        equ  10H   ;offset of File Size field
;
fcb       db      37 dup (?)
filename  db      17 dup(?)
prompt1   db     "File to copy: $"   ;see Function 09H for
prompt2   db     "Name of copy: $"   ;explanation of $
crlf      db      0DH,0AH,"$"
num_recs  dw      ?
buffer    db      32767 dup(?)
;
begin:    set_dta    buffer      ;see Function 1AH
          display    prompt1     ;see Function 09H
          get_string 15,filename ;see Function 0AH
          display    crlf        ;see Function 09H
          parse      filename[2],fcb  ;see Function 29H
          open       fcb              ;see Function 0FH
          mov        fcb[current_record],0;set Current Record field
          set_relative_record fcb     ;see Function 24H
          mov        ax, word ptr fcb[fil_size]
                                      ;get file size
          mov        num_recs,ax      ;save it
          ran_block_read  fcb,num_recs,1  ;THIS FUNCTION
          display    prompt2          ;see Function 09H
          get_string 15,filename      ;see Function 0AH
          display    crlf             ;see Function 09H
          parse      filename[2],fcb  ;see Function 29H
          create     fcb              ;see Function 16H
          mov        fcb[current_record],0  ;set Current Record field
          set_relative_record fcb     ;see Function 24H
          ran_block_write fcb,num_recs,1 ;see Function 28H
          close      fcb              ;see Function 10H
```

Parse File Name (Function 29H)

Call:

AH = 29H
AL
  Controls parsing (see text)
DS:SI
  Pointer to string to parse
ES:DI
  Pointer to buffer for unopened FCB

Return:

AL
  00H   = No wildcard characters
  01H   = Wildcard characters used
  FFH   = Drive letter invalid
DS:SI

Pointer to first byte past
string that was parsed
ES:DI
Pointer to unopened FCB

Comments:

Function 29H parses a string for a filename of the form drive:filename.extension. SI must contain the offset (to the segment address in DS) of the string to parse; DI must contain the offset (to the segment address in ES) of an area of memory large enough to hold an unopened FCB. If the string contains a valid filename, this call creates a corresponding unopened FCB at ES:DI.

AL controls the parsing. Bits 4-7 must be 0; bits 0-3 have the following meaning:

Table 1.20
Bit values for Function 29H

Bit	Value	Meaning
0	0	Stop parsing if a file separator is encountered.
Bit	Value	Meaning
0	0	Stop parsing if a file separator is encountered.
	1	Ignore leading separators.
1	0	Set the drive number in the FCB to 0 (current drive) if the string does not contain a drive number.
	1	Leave the drive number in the FCB unchanged if the string does not contain a drive number.
2	0	Set the filename in the FCB to eight blanks if the string does not contain a filename.
	1	Leave the filename in the FCB unchanged if the string does not contain a filename.
3	1	Leave the extension in the FCB unchanged if the string does not contain an extension.
Bit	Value	Meaning
	0	Set the extension in the FCB to three blanks if the string does not contain an extension.

If the string contains a filename or extension that includes an asterisk (*), all remaining characters in the name or extension are set to question marks (?).

Filename separators:

: ; . , = + / " [ ] \ < > | space tab

Filename terminators include all the filename separators, plus any control character. A filename cannot contain a filename terminator, since if the call encounters one, parsing stops.

If the string contains a valid filename:

- AL returns 1 if the filename or extension contains a wildcard character (* or ?); AL returns 0 if neither the filename nor extension contains a wildcard character.

- DS:SI points to the first character following the parsed string.

- ES:DI points to the first byte of the unopened FCB.

If the drive letter is invalid, AL returns FFH. If the string does not contain a valid filename, ES:DI+1 points to a blank.

Macro Definition:

```
parse macro string,fcb
      mov   si,offset string
      mov   di,offset fcb
      push  es
      push  ds
      pop   es
      mov   al,0FH        ;bits 0-3 on
      mov   ah,29H
      int   21H
      pop   es
      endm
```

Example:

The following program verifies the existence of the file named in reply to the prompt.

```
fcb           db      37 dup (?)
prompt        db     "Filename: $"
reply         db      17 dup(?)
yes           db     "File exists",0DH,0AH,"$"
no            db     "File does not exist",0DH,0AH,"$"
              crlf    db 0DH,0AH,"$"
;
begin:        display    prompt        ;see Function 09H
              get_string 15,reply      ;see Function 0AH
              parse      reply[2],fcb  ;THIS FUNCTION
              display    crlf          ;see Function 09H
              search_first  fcb        ;see Function 11H
              cmp        al,0FFH       ;dir. entry found?
              je         not_there     ;no
              display    yes           ;see Function 09H
              jmp        return
not_there:    display    no
```

Get Date (Function 2AH)

Call:

AH = 2AH

Return:

CX
  Year (1980-2099)
DH
  Month (1-12)
DL
  Day (1-31)
AL
  Day of week (0=Sun., 6=Sat.)

Comments:

Function 2AH returns the current date set in the operating system as binary numbers in CX and DX:

Register	Contents
CX	Year (1980-2099)
DH	Month (1=January, 2=February, etc.)
DL	Day of month (1-31)
AL	Day of week (0=Sunday, 1=Monday, etc.)

Macro Definition:

```
get_date  macro
          mov   ah,2AH
          int   21H
          endm
```

Example:

The following program gets the date, increments the day, increments the month or year, if necessary, and sets the new date.

```
month      db      31,28,31,30,31,30,31,31,30,31,30,31
;
begin:     get_date            ;THIS FUNCTION
           inc    dl           ;increment day
           xor    bx,bx        ;so BL can be used as index
           mov    bl,dh        ;move month to index register
           dec    bx           ;month table starts with 0
           cmp    dl,month[bx] ;past end of month?
           jle    month_ok     ;no, set new date
           mov    dl,1         ;yes, set day to 1
           inc    dh           ;and increment month
           cmp    dh,12        ;past end of year?
           jle    month_ok     ;no, set new date
           mov    dh,1         ;yes, set month to 1
           inc    cx           ;increment year
month_ok:  set_date cx,dh,dl   ;see Function 2AH
```

Set Date (Function 2BH)

Call:

AH = 2BH
CX
  Year (1980-2099)
DH
  Month (1-12)

DL
  Day (1-31)

Return:

AL
  00H   = Date was valid
  FFH   = Date was invalid

Comments:

Function 2BH sets the date in the operating system (and in the CMOS clock, if one exists). Registers CX and DX must contain a valid date in binary:

Register	Contents
CX	Year (1980-2099)
DH	Month (1=January, 2=February, etc.)
DL	Day of month (1-31)

If the date is valid, the call sets it and AL returns 0. If the date is not valid, the function aborts and AL returns FFH.

Macro Definition:

```
set_date  macro  year,month,day
          mov    cx,year
          mov    dh,month
          mov    dl,day
          mov    ah,2BH
          int    21H
          endm
```

Example:

The following program gets the date, increments the day, increments the month or year, if necessary, and sets the new date.

```
month      db      31,28,31,30,31,30,31,31,30,31,30,31
;
begin:     get_date            ;see Function 2AH
           inc    dl           ;increment day
           xor    bx,bx        ;so BL can be used as index
           mov    bl,dh        ;move month to index register
           dec    bx           ;month table starts with 0
           cmp    dl,month[bx] ;past end of month?
           jle    month_ok     ;no, set the new date
           mov    dl,1         ;yes, set day to 1
           inc    dh           ;and increment month
           cmp    dh,12        ;past end of year?
           jle    month_ok     ;no, set the new date
           mov    dh,1         ;yes, set the month to 1
           inc    cx           ;increment year
month_ok:  set_date cx,dh,dl   ;THIS FUNCTION
```

Get Time (Function 2CH)

Call:

AH = 2CH

Return:

CH
  Hour (0-23)
CL
  Minutes (0-59)
DH
  Seconds (0-59)
DL
  Hundredths (0-99)

Comments:

Function 2CH returns the current time set in the operating system (and sets the CMOS clock, if one exists) as binary numbers in CX and DX:

Register	Contents
CH	Hour (0-23)
CL	Minutes (0-59)
DH	Seconds (0-59)
DL	Hundredths of a second (0-99)

Depending on how your hardware keeps time, some of these fields may be irrelevant. As an example, many CMOS clock chips do not resolve more than seconds. In such a case, the value in DL will probably always be 0.

Macro Definition:

```
get_time  macro
          mov   ah,2CH
          int   21H
          endm
```

Example:

The following program displays the time continuously until you press any key.

```
time         db    "00:00:00.00",0DH,"$"
;
begin:       get_time               ;THIS FUNCTION
             byte_to_dec ch,time    ;see end of chapter
             byte_to_dec cl,time[3] ;see end of chapter
             byte_to_dec dh,time[6] ;see end of chapter
             byte_to_dec dl,time[9] ;see end of chapter
             display time           ;see Function 09H
             check_kbd_status       ;see Function 0BH
             cmp     al,0FFH        ;has a key been pressed?
             je      return         ;yes, terminate
             jmp     begin          ;no, display time
```

Set Time (Function 2DH)

Call:

```
AH = 2DH
CH
  Hour (0-23)
CL
  Minutes (0-59)
DH
  Seconds (0-59)
DL
  Hundredths (0-99)
```

Return:

```
AL
  00H     = Time was valid
  FFH     = Time was invalid
```

Comments:

Function 2DH sets the time in the operating system. Registers CX and DX must contain a valid time in binary:

Register	Contents
CH	Hour (0-23)
CL	Minutes (0-59)
DH	Seconds (0-59)
DL	Hundredths of a second (0-9)

Depending on how your hardware keeps time, some of these fields may be irrelevant. As an example, many CMOS clock chips do not resolve more than seconds. In such a case, the value in DL will not be relevant.

If the time is valid, the call sets it and AL returns 0. If the time is not valid, the function aborts and AL returns FFH.

Macro Definition:

```
set_time  macro  hour,minutes,seconds,hundredths
          mov    ch,hour
          mov    cl,minutes
          mov    dh,seconds
          mov    dl,hundredths
          mov    ah,2DH
          int    21H
          endm
```

Example:

The following program sets the system clock to 0 and displays the time continuously. When you type a character, the display freezes; when you type another character, the clock is reset to 0 and the display starts again.

```
time          db  "00:00:00.00",0DH,0AH,"$"
;
begin:        set_time  0,0,0,0       ;THIS FUNCTION
read_clock:   get_time                ;see Function 2CH
              byte_to_dec  ch,time    ;see end of chapter
              byte_to_dec  cl,time[3] ;see end of chapter
              byte_to_dec  dh,time[6] ;see end of chapter
```

```
              byte_to_dec  dl,time[9] ;see end of chapter
              display  time           ;see Function 09H
              dir_console_io 0FFH     ;see Function 06H
              cmp      al,00H         ;was a char. typed?
              jne      stop           ;yes, stop the timer
              jmp      read_clock     ;no keep timer on
stop:         read_kbd                ;see Function 08H
              jmp      begin          ;keep displaying time
```

Set/Reset Verify Flag (Function 2EH)

Call:

AH = 2EH
AL
  0 = Do not verify
  1 = Verify

Return:

None

Comments:

Function 2EH tells MS-DOS whether to verify each disk write. If AL is 1, verify is on; if AL is 0, verify is off. MS-DOS checks this flag each time it writes to a disk.

The flag is normally off; you may wish to turn it on when writing critical data to disk. Because disk errors are rare and verification slows writing, you will probably want to leave it off at other times. You can check the setting with Function 54H (Get Verify State).

Macro Definition:

```
verify  macro  switch
        mov    al,switch
        mov    ah,2EH
        int    21H
        endm
```

Example:

The following program copies the contents of a single-sided disk in drive A to the disk in drive B, verifying each write. It uses a buffer of 32K bytes.

```
on           equ   1
off          equ   0
;
prompt       db   "Source in A, target in B",0DH,0AH
             db   "Any key to start. $"
first        dw    0
buffer       db    60 dup (512 dup(?))   ;60 sectors
;
begin:       display prompt              ;see Function 09H
             read_kbd                    ;see Function 08H
             verify on                   ;THIS FUNCTION
```

```
            mov    cx,6                ;copy 60 sectors
                                       ;6 times
copy:       push   cx                  ;save counter
            abs_disk_read  0,buffer,60,first ;see Int 25H
            abs_disk_write  1,buffer,64,first ;see Int 26H
            add    first,60            ;do next 60 sectors
            pop    cx                  ;restore counter
            loop   copy                ;do it again
            verify off                 ;THIS FUNCTION
```

Get Disk Transfer Address (Function 2FH)

Call:

AH = 2FH

Return:

ES:BX
  Pointer to Disk Transfer Address

Comments:

Function 2FH returns the segment address of the current Disk Transfer Address in ES and the offset in BX.

Macro Definition:

```
get_dta  macro
         mov    ah,2fH
         int    21H
         endm
```

Example:

The following program displays the current Disk Transfer Address in the form: segment:offset.

```
message   db      "DTA --        :    ",0DH,0AH,"$"
sixteen   db       10H
temp      db       2 dup (?)
;
begin:    get_dta                     ;THIS FUNCTION
          mov    word ptr temp,ex     ;To access each byte
          convert temp[1],sixteen,message[07H]  ;See end of
          convert temp,sixteen,message[09H]    ;chapter for
          convert bh,sixteen,message[0CH]      ;description
          convert bl,sixteen,message[0EH]      ;of CONVERT
          display message             ;See Function 09H
```

Get MS-DOS Version Number (Function 30H)

Call:

AH = 30H

Return:

AL
  Major version number
AH
  Minor version number
BH
  OEM serial number
BL:CX
  24-bit user (serial) number

Comments:

Function 30H returns the MS-DOS version number. AL returns the major version number; AH returns the minor version number. (For example, MS-DOS 3.0 returns 3 in AL and 0 in AH.)

If AL returns 0, the MS-DOS version is earlier than 2.0.

Macro Definition:

```
get_version  macro
             mov    ah,30H
             int    21H
             endm
```

Example:

The following program displays the MS-DOS version if it is 1.28 or greater.

```
message   db      "MS-DOS Version  . ",0DH,0AH,"$"
ten       db       0AH                 ;For CONVERT
;
begin:    get_version                  ;THIS FUNCTION
          cmp     al,0                 ;1.28 or later?
          jng     return               ;No, go home
          convert al,ten,message[0FH]  ;See end of chapter
          convert ah,ten,message[12H]  ;for description
          display message              ;See Function 09H
```

Keep Process (Function 31H)

Call:

AH = 31H
AL
  Return code
DX
  Memory size, in paragraphs

Return:

None

Comments:

Function 31H makes a program remain resident after it terminates. You can use it to install device-specific interrupt handlers. But unlike Interrupt 27H (Terminate But Stay Resident), this function request allows more than 64K bytes to remain resident and does not require CS to contain the segment address of the Program Segment Prefix. You should use Function 31H to install a resident program unless your program must be compatible with MS-DOS versions earlier than 2.0.

DX must contain the number of paragraphs of memory required by the program (one paragraph = 16 bytes). AL contains an exit code.

Be careful when using this function with .exe programs. The value in DX must be the total size to remain resident, not just the size of the code segment which is to remain resident. A typical error is to forget about the 100H-byte program-header-prefix and give a value in DX that is 10H too small.

MS-DOS terminates the current process and tries to set the memory allocation to the number of paragraphs in DX. No other allocation blocks belonging to the process are released.

By using Function 4DH (Get Return Code of Child Process), the parent process can retrieve the process's exit code from AL. (You can test this exit code by using the if command with errorlevel.)

Macro Definition:

```
keep_process  macro return_code,last_byte
              mov   al,return_code
              mov   dx,offset last_byte
              mov   cl,4
              shr   dx,cl
              inc   dx
              mov   ah,31H
              int   21H
              endm
```

Example:

Because the most common use of this call is to install a machine-specific routine, an example is not shown. The macro definition, however, shows the calling syntax.

CONTROL-C Check (Function 33H)

Call:

```
AH = 33H
AL
   0 = Get state
   1 = Set state
DL (if AL=1)
   0 = Off
   1 = On
```

Return:

```
DL (if AL=0)
   0 = Off
```

```
   1 = On
AL
   FFH = error (AL was neither 0 nor 1
         when call was made)
```

Comments:

Function 33H gets or sets the state of CONTROL-C (or CONTROL-BREAK for IBM compatibles) checking in MS-DOS. AL must contain a code that specifies the requested action:

Code	Meaning
0	Current state of CONTROL-C checking in DL
1	Set state of CONTROL-C checking to the value in DL

If AL is 0, DL returns the current state (0=off, 1=on). If AL is 1, the value in DL specifies the state to be set (0=off, 1=on). If AL is neither 0 nor 1, AL returns FFH and the state of CONTROL-C checking is unaffected.

MS-DOS normally checks for CONTROL-C only when carrying out certain function requests in the 01H through 0CH group (see the description of specific calls for details). When CONTROL-C checking is on, MS-DOS checks for CONTROL-C when carrying out any function request. For example, if CONTROL-C checking is off, all disk I/O proceeds without interruption, but if it is on, the CONTROL-C interrupt is issued at the function request that initiates the disk operation.

.....
Note
  Programs that use Function 06H (Direct Console I/O) or 07H (Direct Console Input) to read CONTROL-C as data must ensure that the CONTROL-C checking is off.
.....

Macro Definition:

```
ctrl_c_ck  macro  action,state
           mov    al,action
           mov    dl,state
           mov    ah,33H
           int    21H
           endm
```

Example:

The following program displays a message that tells whether CONTROL-C checking is on or off:

```
message   db       "CONTROL-C checking ","$"
on        db       "on","$",0DH,0AH,"$"
off       db       "off","$",0DH,0AH,"$"
;
begin:    display  message          ;See Function 09H
          ctrl_c_ck 0               ;THIS FUNCTION
          cmp      dl,0             ;Is checking off?
          jg       ck_on            ;No
          display  off              ;See Function 09H
          jmp      return           ;Go home
ck_on:    display  on               ;See Function 09H
```

Get Interrupt Vector (Function 35H)

Call:

AH = 35H
AL
   Interrupt number

Return:

ES:BX
   Pointer to interrupt routine

Comments:

Function 35H gets the address from the interrupt-vector table for the specified interrupt. AL must contain the number of an interrupt.

ES returns the segment address of the interrupt handler; BX returns the offset.

To avoid compatibility problems, programs should never read an interrupt vector directly from memory, nor set an interrupt vector by writing it into memory. Use this function request to get a vector and Function 25H (Set Interrupt Vector) to set a vector, unless your program must be compatible with MS-DOS versions earlier than 2.0.

Macro Definition:

```
get_vector  macro  interrupt
            mov    al,interrupt
            mov    ah,35H
            int    21H
            endm
```

Example:

The following program displays the segment and offset (CS:IP) for the handler for Interrupt 25H (Absolute Disk Read).

```
message   db     "Interrupt 25H -- CS:0000 IP:0000"
          db      0DH,0AH,"$"
vec_seg   db      2 dup (?)
vec_off   db      2 dup (?)
;
begin:    push    es                    ;save ES
          get_vector 25H                ;THIS FUNCTION
          mov     ax,es                 ;INT25H segment in AX
          pop     es                    ;save ES
          convert ax,16,message[20]     ;see end of chapter
          convert bx,16,message[28]     ;see end of chapter
          display message               ;See Function 09H
```

Get Disk Free Space (Function 36H)

Call:

AH = 36H
DL
   Drive (0=default, 1=A, etc.)

Return:

AX
   0FFFFH if drive number is invalid;
   otherwise, sectors per cluster
BX
   Available clusters
CX
   Bytes per sector
DX
   Clusters per drive

Comments:

Function 36H returns the number of clusters available on the disk in the specified drive, and the information necessary to calculate the number of bytes available on the disk. DL must contain a drive number (0=default, 1=A, etc.). If the drive number is valid, MS-DOS returns the information in the following registers:

Register	Contents
AX	Sectors per cluster
BX	Available clusters
CX	Bytes per sector
DX	Total clusters

If the drive number is invalid, AX returns 0FFFFH.

This call supersedes Functions 1BH and 1CH in earlier MS-DOS versions.

Macro Definition:

```
get_disk_space  macro  drive
                mov    dl,drive
                mov    ah,36H
                int    21H
                endm
```

Example:

The following program displays the space information for the disk in drive B.

```
message   db "      clusters on drive B.",0DH,0AH   ;DX
          db "      clusters available.",0DH,0AH    ;BX
          db "      sectors per cluster.",0DH,0AH   ;AX
          db "      bytes per sector,",0DH,0AH,"$"  ;CX
;
begin:    get_disk_space 2                ;THIS FUNCTION
          convert    ax,10,message[55]    ;see end of chapter
          convert    bx,10,message[28]    ;see end of chapter
          convert    cx,10,message[83]    ;see end of chapter
          convert    dx,10,message        ;see end of chapter
          display message                 ;See Function 09H
```

Get Country Data (Function 38H)

Call:

```
AH = 38H
AL
   00H    = Current country
   1-0FEH = Country code
   0FFH   = BX contains country code
BX (if AL = 0FFH)
   Country code 255 or higher
DS:DX
   Pointer to 32-byte memory area
```

Return:

```
Carry set:
AX
   2 = Invalid country code
Carry not set:
BX
   Country code
```

Comments:

Function 38H gets the country-dependent information that MS-DOS uses to control the keyboard and display, or it sets the currently defined country (to set the country code, see the next function request description, Set Country Data). To get the information, DX must contain the offset (from the segment address in DS) of a 32-byte memory area to which the country data returns. AL specifies the country code:

Value in AL	Meaning
00H	Retrieve information about the country currently set.
1 to 0FEH	Retrieve information about the country identified by this code.
0FFH	Retrieve information about the country identified by the code in BX.

BX must contain the country code if the code is 255 or greater. The country code is usually the international telephone-prefix code.

The country-dependent information returns in the following form:

Offset Hex	Offset Decimal	Field Name	Length in bytes
00H	0	Date format	2 (word)
02H	2	Currency symbol	5 (ASCIZ string)
07H	7	Thousands separator	2 (ASCIZ string)
09H	9	Decimal separator	2 (ASCIZ string)
0BH	11	Date separator	2 (ASCIZ string)
0DH	13	Time separator	2 (ASCIZ string)
0FH	15	Bit field	1
10H	16	Currency places	1
11H	17	Time format	1

12H	18	Case-map call address	4 (DWORD)
16H	22	Data-list separator	2 (ASCIZ string)
18H	24	Reserved	10

Date Format:

0 = USA (month/day/year)
1 = Europe (day/month/year)
2 = Japan (year/month/day)

Bit Field:

Bit	Value	Meaning
0	0	Currency symbol precedes amount
	1	Currency symbol follows amount
1	0	No space between symbol and amount
	1	One space between symbol and amount

All other bits are undefined.

Time format:

0 = 12-hour clock
1 = 24-hour clock

Currency Places:

Specifies the number of places that appear after the decimal point on currency amounts.

Case-Mapping Call Address:

Specifies the segment and offset of a FAR procedure that performs country-specific lowercase-to-uppercase mapping on character values from 80H to 0FFH. You call it with the character to be mapped in AL. If there is an uppercase code for the character, it is returned in AL; if there is not, or if you call it with a value less than 80H in AL, AL returns unchanged. AL and the FLAGS are the only altered registers.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	Invalid country code (no table for it).

Macro Definition:

```
get_country   macro  country,buffer
              local     gc_01
              mov       dx,offset buffer
              mov       ax,country
              cmp       ax,OFFH
              jl        gc_01
              mov       al,OFFh
              mov       bx,country
gc_01:        mov       ah,38h
```

```
              int       21H
              endm
```

Example:

The following program displays the time and date in the format appropriate to the current country code, and the number 999,999 and 99/100 as a currency amount with the proper currency symbol and separators.

```
time       db     "  :  :  ",5 dup (20H),"$"
date       db     "  /  /  ",5 dup (20H),"$"
number     db     "999?999?99",0DH,0AH,"$"
data_area  db      32 dup (?)
;
begin:    get_country  0,data_area       ;THIS FUNCTION
          get_time                       ;See Function 2CH
          byte_to_dec  ch,time           ;See end of chapter
          byte_to_dec  cl,time[03H]      ;for description of
          byte_to_dec  dh,time[06H]      ;CONVERT macro
          get_date                       ;See Function 2AH
          sub      cx,1900               ;Want last 2 digits
          byte_to_dec  cl,date[06H]      ;See end of chapter
          cmp      word ptr data_area,0  ;Check country code
          jne      not_usa               ;It's not USA
          byte_to_dec  dh,date           ;See end of chapter
          byte_to_dec  dl,date[03H]      ;See end of chapter
          jmp      all_done              ;Display data
not_usa:  byte_to_dec  dl,date           ;See end of chapter
          byte_to_dec  dh,date[03H]      ;See end of chapter
all_done: mov      al,data_area[07H]     ;Thousand separator
          mov      number[03H],al        ;Put in NUMBER
          mov      al,data_area[09H]     ;Decimal separator
          mov      number[07H],al        ;Put in AMOUNT
          display  time                  ;See Function 09H
          display  date                  ;See Function 09H
          display_char  data_area[02H]   ;See Function 02H
          display  number                ;See Function 09H
```

Set Country Data (Function 38H)

Call:

AH = 38H
DX = -1 (0FFFFH)
AL
   Country code less than 255, or
   0FFH if the country code is in BX
BX (if AL=0FFH)
   Country code 255 or higher

Return:

Carry set:
AX
   2 = Invalid country code
Carry not set:
   No error

Comments:

Function 38H sets the country code that MS-DOS uses to control the keyboard and the display, or it retrieves the country-dependent information (to get the country data, see the previous function request description, "Get Country Data"). To set the information, DX must contain 0FFFFH. AL must contain either the country code, if it is less than 255, or 255 to indicate that the country code is in BX. If AL contains 0FFH, BX must contain the country code.

The country code is usually the international telephone prefix-code. See "Get Country Data" for a description of the country data and how it is used.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	Invalid country code (no table for it).

Macro Definition:

```
set_country macro  country
            local  sc_01
            mov    dx,0FFFFH
            mov    ax,country
            cmp    ax,0FFH
            jl     sc_01
            mov    bx,country
            mov    al,0ffh
sc_01:      mov    ah,38H
            int    21H
            endm
```

Example:

The following program sets the country code to the United Kingdom (44).

```
uk        equ         44
;
begin:    set_country uk     ;THIS FUNCTION
          jc          error  ;routine not shown
```

Create Directory (Function 39H)

Call:

AH = 39H
DS:DX
   Pointer to pathname

Return:

Carry set:
AX
   2 = File not found
   3 = Path not found
   5 = Access denied
Carry not set:

No error

Comments:

Function 39H creates a new subdirectory. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the pathname of the new subdirectory.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	File not found
3	Path not found
5	No room in the parent directory, a file with the same name exists in the current directory, or the path specifies a device

Macro Definition:

```
make_dir  macro path
          mov    dx,offset path
          mov    ah,39H
          int    21H
          endm
```

Example:

The following program adds a subdirectory named new_dir to the root directory on the disk in drive B and changes the current directory to new_dir. The program then changes the current directory back to the original directory and then deletes new_dir. It displays the current directory after each step to confirm the changes.

```
old_path  db        "b:
new_path  db        "b:\new_dir",0
buffer    db        "b:
;
begin:    get_dir    2,old_path[03H]  ;See Function 47H
          jc         error_get        ;Routine not shown
          display_asciz  old_path     ;See end of chapter
          make_dir   new_path         ;THIS FUNCTION
          jc         error_make       ;Routine not shown
          change_dir new_path         ;See Function 3BH
          jc         error_change     ;Routine not shown
          get_dir    2,buffer[03H]    ;See Function 47H
          jc         error_get        ;Routine not shown
          display_asciz  buffer       ;See end of chapter
          change_dir old_path         ;See Function 3BH
          jc         error_change     ;Routine not shown
          rem_dir    new_path         ;See Function 3AH
          jc         error_rem        ;Routine not shown
          get_dir    2,buffer[03H]    ;See Function 47H
          jc         error_get        ;Routine not shown
          display_asciz  buffer       ;See end of chapter
```

Remove Directory (Function 3AH)

Call:

AH = 3AH
DS:DX
   Pointer to pathname

Return:

Carry set:
AX
   2 = File not found
   3 = Path not found
   5 = Access denied
  16 = Current directory
Carry not set:
   No error

Comments:

Function 3AH deletes a subdirectory. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the pathname of the subdirectory you want to delete.

The subdirectory must not contain any files. You cannot erase the current directory. If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	File not found
3	Path not found
5	Directory not empty, or path doesn't specify a directory, or it specifies the root directory, or it is invalid
16	Path specifies current directory

Macro Definition:

```
rem_dir  macro  path
         mov    dx,offset path
         mov    ah,3AH
         int    21H
         endm
```

Example:

The following program adds a subdirectory named new_dir to the root directory on the disk in drive B and changes the current directory to new_dir. The program then changes the current directory back to the original directory and deletes new_dir. It displays the current directory after each step to confirm the changes.

```
old_path  db        "b:
new_path  db        "b:\new_dir",0
buffer    db        "b:
;
begin:    get_dir    2,old_path[03H]  ;See Function 47H
```

```
          jc         error_get        ;Routine not shown
          display_asciz  old_path     ;See end of chapter
          make_dir   new_path         ;See Function 39H
          jc         error_make       ;Routine not shown
          change_dir new_path         ;See Function 3BH
          jc         error_change     ;Routine not shown
          get_dir    2,buffer[03H]    ;See Function 47H
          jc         error_get        ;Routine not shown
          display_asciz  buffer       ;See end of chapter
          change_dir old_path         ;See Function 3BH
          jc         error_change     ;Routine not shown
          rem_dir    new_path         ;THIS FUNCTION
          jc         error_rem        ;Routine not shown
          get_dir    2,buffer[03H]    ;See Function 47H
          jc         error_get        ;Routine not shown
          display_asciz  buffer       ;See end of chapter
```

Change Current Directory (Function 3BH)

Call:

AH = 3BH
DS:DX
   Pointer to pathname

Return:

Carry set:
AX
   2 = File not found
   3 = Path not found
Carry not set:
   No error

Comments:

Function 3BH changes the current directory. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the pathname of the new current directory.

The directory string is limited to 64 characters.

If any member of the path doesn't exist, the path is unchanged.
If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	File not found
3	Path either doesn't exist or it specifies a file instead of a directory

Macro Definition:

```
change_dir  macro  path
            mov    dx,offset path
            mov    ah,3BH
            int    21H
```

```
            endm
```

Example:

The following program adds a subdirectory named new_dir to the root directory that is on the disk in drive B and changes the current directory to new_dir. The program then changes the current directory back to the original directory and deletes new_dir. It displays the current directory after each step to confirm the changes.

```
old_path  db        "b:
new_path  db        "b:\new_dir",0
buffer    db        "b:
;
begin:    get_dir    2,old_path[03H]  ;See Function 47H
          jc         error_get        ;Routine not shown
          display_asciz  old_path     ;See end of chapter
          make_dir   new_path         ;See Function 39H
          jc         error_make       ;Routine not shown
          change_dir new_path         ;THIS FUNCTION
          jc         error_change     ;Routine not shown
          get_dir    2,buffer[03H]    ;See Function 47H
          jc         error_get        ;Routine not shown
          display_asciz  buffer       ;See end of chapter
          change_dir old_path         ;See Function 3BH
          jc         error_change     ;Routine not shown
          rem_dir    new_path         ;See Function 3AH
          jc         error_rem        ;Routine not shown
          get_dir    2,buffer[03H]    ;See Function 47H
          jc         error_get        ;Routine not shown
          display_asciz  buffer       ;See end of chapter
```

Create Handle (Function 3CH)

Call:

AH = 3CH
DS:DX
   Pointer to pathname
CX
   File attribute

Return:

Carry set:
AX
   2 = File not found
   3 = Path not found
   4 = Too many open files
   5 = Access denied
Carry not set:
AX
   Handle

Comments:

Function 3CH creates a file and assigns it the first available handle. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the pathname of the file to be created. CX must contain the

attribute to be assigned to the file, as described under "File Attributes" earlier in this chapter.

If the specified file does not exist, this function creates it. But if the file already exists, it is truncated to a length of 0. Function 3CH then assigns the attribute in CX to the file and opens it for read/write. AX returns the file handle.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	File not found
3	Path is invalid
4	Too many open files (no handle available)
5	Directory is full, a directory with the same name exists, or a file with the same name exists with more restrictive attributes

Macro Definition:

```
create_handle  macro  path,attrib
               mov    dx,offset path
               mov    cx,attrib
               mov    ah,3CH
               int    21H
               endm
```

Example:

The following program creates a file named dir.tmp, containing the name and extension of each file in the current directory, on the disk in drive B.

```
srch_file db      "b:*.*",0
tmp_file  db      "b:dir.tmp",0
buffer    db       43 dup (?)
handle    dw       ?
;
begin:    set_dta buffer                ;See Function 1AH
          find_first_file  srch_file,16H  ;See Function 4EH
          cmp     ax,12H                ;Directory empty?
          je      all_done              ;Yes, go home
          create_handle  tmp_file,0     ;THIS FUNCTION
          jc      error                 ;Routine not shown
          mov     handle,ax             ;Save handle
write_it: write_handle handle,buffer[1EH],12 ;Function 40H
          find_next_file                ;See Function 4FH
          cmp     ax,12H                ;Another entry?
          je      all_done              ;No, go home
          jmp     write_it              ;Yes, write record
all_done: close_handle  handle          ;See Function 3EH
```

Open Handle (Function 3DH)

Call:

AH = 3DH

AL
   Access code (see text)
DS:DX
   Pointer to pathname

Return:

Carry set:
AX
   2   = File not found
   3   = Path not found
   4   = Too many open files
   5   = Access denied
  12   = Invalid access
Carry not set:
   No error

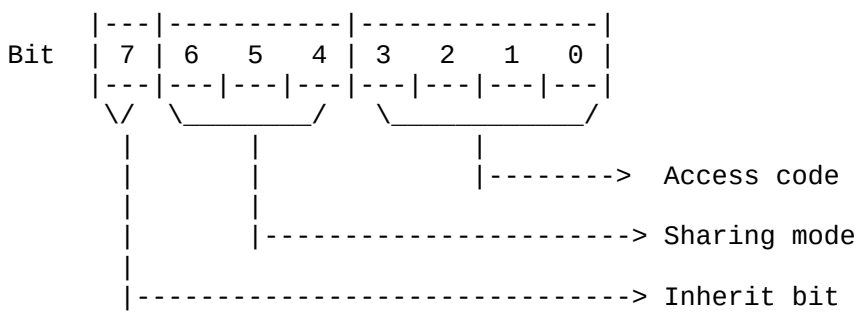
Comments:

Function 3DH opens any file, including hidden and system files, for input or output. DX contains the offset (from the segment address in DS) of an ASCIZ string that specifies the pathname of the file to be opened. AL contains a code that specifies how the file is to be opened. This code is described later under "Controlling Access to the File."

If there is no error, AX returns the file handle. MS-DOS sets the read/write pointer to the first byte of the file.

Controlling Access to the File

The value in AL is made up of three parts that specify whether the file is to be opened for read, write, or both (access code); what access other processes have to the file (sharing mode); and whether a child process inherits the file (inherit bit).



Inherit Bit

The high-order bit (bit 7) specifies whether the file is inherited by a child process created with Function 4BH (Load and Execute Program). If the bit is 0, the child process inherits the file; if the bit is 1, it doesn't.

Sharing Mode

The sharing mode bits (bits 4-6) specify what access, if any, other processes have to the open file. It can have the following values:

Table 1.21
Sharing Mode Bit Values

Bits 4-6	Sharing Mode	Description
000	Compatibility	On a given machine, any process can open the file any number of times with this mode. Fails if the file has been opened with any of the other sharing modes.
001	Deny both	Fails if the file has been opened in compatibility mode or for read or write access, even if by the current process.
010	Deny write	Fails if the file has been opened in compatibility mode or for write access by any other process.
011	Deny read	Fails if the file has been opened in compatibility mode or
Bits 4-6	Sharing Mode	Description
#		opened in compatibility mode or for read access by any other process.
100	Deny none	Fails if the file has been opened in compatibility mode by any other process.

Access Code

The access code (bits 0-3) specifies how the file is to be used. It can have the following values:

Table 1.22
Access Code Bit Values

Bit 0-3	Access Allowed	Description
Bit 0-3	Access Allowed	Description
0000	Read	Fails if the file has been opened in deny read or deny both sharing mode.
0001	Write	Fails if the file has been opened in deny write or deny both sharing mode.
0010	Both	Fails if the file has been opened in deny read, deny write, or deny both sharing mode.

If there is an error, the carry flag (CF) is set and the error code is returned in AX:

Code	Meaning

2 Specified file is invalid or doesn't exist

3 Specified path is invalid or doesn't exist

4 No handles are available in the current process or the internal system tables are full

5 Program attempted to open a directory or VolumeID, or tried to open a read-only file for writing

12 Access code (bits 0-3 of AL) not 0, 1, or 2

If this system call fails because of a file-sharing error, MS-DOS issues Interrupt 24H with error code 2 (Drive Not Ready). A subsequent Function 59H (Get Extended Error) returns the extended error code that specifies a sharing violation.

When opening a file, it is important to inform MS-DOS of any operations that other processes may perform on this file (sharing mode). The default (compatibility mode) denies all other processes access to the file, unless they also attempt to open the file in compatibility mode.

The following table shows the effect of opening a file with compatibility mode set:

Type of File Opening	Read-Only File	Not Read-Only
First open for read, write, or both by machine/process "N"	Succeeds	Succeeds
Subsequent opens by machine or process "N"	Succeeds	Succeeds
An open by another machine or process	Succeeds	Fails

Files may be read-only with the MS-DOS attrib command or by a read-only share over the network.

It may be all right for other processes to continue to read the file while your process is operating on it. In this case, you should specify "Deny Write," which inhibits other processes from writing to your files but allows them to read from these files.

Similarly, it is important for you to specify what operations your process will perform ("Access" mode). If another process has the file open with any sharing mode other than "Deny" mode, then the default mode ("Read/write") causes the open request to fail. If you only want to read the file, your open request succeeds unless all other processes have specified "Deny" mode or "Deny write."

Macro Definition:

```
open_handle  macro  path,access
             mov    dx, offset path
             mov    al, access
             mov    ah, 3DH
             int    21H
             endm
```

Example:

The following program prints a file named textfile.asc that is on the disk in drive B.

```
file       db  "b:textfile.asc",0
buffer     db   ?
handle     dw   ?
;
begin:     open_handle  file,0          ;THIS FUNCTION
           mov  handle,ax               ;Save handle
read_char: read_handle handle,buffer,1  ;Read 1 character
           jc   error_read              ;Routine not shown
           cmp  ax,0                    ;End of file?
           je   return                  ;Yes, go home
           print_char  buffer           ;See Function 05H
           jmp  read_char               ;Read another
```

Close Handle (Function 3EH)

Call:

AH = 3EH
BX
   Handle

Return:

Carry set:
AX
   6 = Invalid handle
Carry not set:
   No error

Comments:

Function 3EH closes a file opened with Function 3DH (Open Handle) or 3CH (Create Handle). BX must contain the handle of the open file that you want to close.

If there is no error, MS-DOS closes the file and flushes all internal buffers. If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
6	Handle not open or invalid

Macro Definition:

```
close_handle  macro  handle
              mov    bx,handle
              mov    ah,3EH
              int    21H
              endm
```

Example:

The following program creates a file named dir.tmp, containing the filename

and extension of each file in the current directory, in the current directory on the disk in drive B.

```
srch_file  db  "b:*.*",0
tmp_file   db  "b:dir.tmp",0
buffer     db   43 dup (?)
handle     dw   ?
;
begin:     set_dta  buffer              ;See Function 1AH
           find_first_file  srch_file,16H  ;See Function 4EH
           cmp      ax,12H              ;Directory empty?
           je       all_done            ;Yes, go home
           create_handle  tmp_file,0    ;See Function 3CH
           jc       error_create        ;Routine not shown
           mov      handle,ax           ;Save handle
write_it:  write_handle  handle,buffer[1EH],12 ;See Function 40H
           find_next_file               ;See Function 4FH
           cmp      ax,12H              ;Another entry?
           je       all_done            ;No, go home
           jmp      write_it            ;Yes, write record
all_done:  close_handle  handle         ;See Function 3EH
           jc       error_close         ;Routine not shown
```

Read Handle (Function 3FH)

Call:

```
AH = 3FH
BX
   Handle
CX
   Bytes to read
DS:DX
   Pointer to buffer
```

Return:

```
Carry set:
AX
   5 = Access denied
   6 = Invalid handle
Carry not set:
AX
   Bytes read
```

Comments:

Function 3FH reads from the file or device associated with the specified handle. BX must contain the handle. CX must contain the number of bytes to be read. DX must contain the offset (to the segment address in DS) of the buffer.

If there is no error, AX returns the number of bytes read; if you attempt to read starting at end of file, AX returns 0. The number of bytes specified in CX is not necessarily transferred to the buffer; if you use this call to read from the keyboard, for example, it reads only up to the first carriage-return.

If you use this function request to read from standard input, you can redirect the input.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
5	Handle not open for reading
6	Handle not open or invalid

Macro Definition:

```
read_handle  macro  handle,buffer,bytes
             mov    bx,handle
             mov    dx,offset buffer
             mov    cx,bytes
             mov    ah,3FH
             int    21H
             endm
```

Example:

The following program displays a file named textfile.asc that is on the disk in drive B.

```
filename   db     "b:\textfile.asc",0
buffer     db      129 dup (?)
handle     dw      ?
;
begin:     open_handle  filename,0          ;See Function 3DH
           jc           error_open          ;Routine not shown
           mov          handle,ax           ;Save handle
read_file: read_handle  buffer,file_handle,128
           jc           error_open          ;Routine not shown
           cmp          ax,0                ;End of file?
           je           return              ;Yes, go home
           mov          bx,ax               ;# of bytes read
           mov          buffer[bx],"$"      ;Make a string
           display      buffer              ;See Function 09H
           jmp          read_file           ;Read more
```

Write Handle (Function 40H)

Call:

AH = 40H
BX
   Handle
CX
   Bytes to write
DS:DX
   Pointer to buffer

Return:

Carry set:
AX
   5 = Access denied
   6 = Invalid handle
Carry not set:

AX
   Bytes written

Comments:

Function 40H writes to the file or device associated with the specified handle. BX must contain the handle. CX must contain the number of bytes to be written. DX must contain the offset (to the segment address in DS) of the data to be written.

If you set CX to zero, the file will be truncated at the current position of the file pointer. MS-DOS will not perform the write if the handle is read-only.

If there is no error, AX returns the number of bytes written. Be sure to check AX after performing a write. If its value is less than the number in CX when the call was made, it indicates an error, even though the carry flag isn't set. If AX contains 0, and if the target is a disk file, the disk is full.

If you use this function request to write to standard output, you can redirect the output. If you call this request with CX=0, the file size is set to the value of the read/write pointer. To satisfy the new file size, allocation units are allocated or released, as required.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
5	Handle not open for writing
6	Handle not open or invalid

Macro Definition:

```
write_handle  macro  handle,buffer,bytes
              mov    bx,handle
              mov    dx,offset buffer
              mov    cx,bytes
              mov    ah,40H
              int    21H
              endm
```

Example:

The following program creates a file named dir.tmp, containing the filename and extension of each file in the current directory, in the current directory on the disk in drive B.

```
srch_file db     "b:*.*",0
tmp_file  db     "b:dir.tmp",0
buffer    db      43 dup (?)
handle    dw      ?
;
begin:    set_dta buffer                ;See Function 1AH
          find_first_file  srch_file,16H ;Check directory
          cmp     ax,12H                ;Directory empty?
          je      return                ;Yes, go home
          create_handle  tmp_file,0     ;See Function 3CH
          jc      error_create          ;Routine not shown
          mov     handle,ax             ;Save handle
```

```
write_it: write_handle handle,buffer[1EH],12 ;THIS FUNCTION
          jc      error_write           ;Routine not shown
          find_next_file                ;Check directory
          cmp     ax,12H                ;Another entry?
          je      all_done              ;No, go home
          jmp     write_it              ;Yes, write record
all_done: close_handle  handle          ;See Function 3EH
          jc      error_close           ;Routine not shown
```

Delete Directory Entry [Unlink] (Function 41H)

Call:

AH = 41H
DS:DX
   Pointer to pathname

Return:

Carry set:
AX
   2 = File not found
   3 = Path not found
   5 = Access denied
Carry not set:
   No error

Comments:

Function 41H erases a file by deleting its directory entry. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the pathname of the file that you want to delete. You cannot use wildcard characters.

If the file exists and is not read-only, the call deletes it. If there is an error, the call sets the carry flag (CF) and the error code returns in AX:

Code	Meaning
2	File doesn't exist, or specifies a directory
3	Path is invalid
5	File is read-only

To delete a file with the read-only attribute, first change its attribute to 0 with Function 43H (Get/Set File Attribute).

Macro Definition:

```
delete_entry  macro  path
              mov    dx,offset path
              mov    ah,41H
              int    21H
              endm
```

Example:

The following program deletes all files, dated before December 31, 1986,

from the disk in drive B.

```
year      db       1986
month     db       12
day       db       31
files     db       ?
message   db      "NO FILES DELETED.",0DH,0AH,"$"
path      db      "b:*.*", 0
buffer    db       43 dup (?)
;
begin:    set_dta  buffer           ;See Function 1AH
          select_disk "B"           ;See Function 0EH
          find_first_file  path,0   ;See Function 4EH
          jnc      compare          ;got one
          jmp      all_done         ;no match, go home
compare:  convert_date  buffer[-1]  ;See end of chapter
          cmp      cx,year          ;After 1986?
          jg       next             ;Yes, don't delete
          cmp      dl,month         ;After December?
          jg       next             ;Yes, don't delete
          cmp      dh,day           ;31st or after?
          jge      next             ;Yes, don't delete
          delete_entry  buffer[1EH] ;THIS FUNCTION
          jc       error_delete     ;Routine not shown
          inc      files            ;Bump file counter
next:     find_next_file            ;Check directory
          jnc      compare          ;Go home if done
how_many: cmp      files,0          ;Was directory empty?
          je       all_done         ;Yes, go home
          convert  files,10,message ;See end of chapter
all_done: display  message          ;See Function 09H
          select_disk "A"           ;See Function 0EH
```

Move File Pointer (Function 42H)

Call:

AH = 42H
AL
   Method of moving
BX
   Handle
CX:DX
   Distance in bytes (offset)

Return:

Carry set:
AX
   1 = Invalid function
   6 = Invalid handle
Carry not set:
DX:AX
   New read/write pointer location

Comments:

Function 42H moves the read/write pointer of the file associated with the specified handle. BX must contain the handle. CX and DX must contain a 32-bit offset (CX contains the most significant byte). AL must contain a code

that specifies how to move the pointer:

Code	Cursor Moved to
0	Beginning of file plus the offset
1	Current pointer location plus the offset
2	End of file plus the offset

DX and AX return the new location of the read/write pointer (a 32-bit integer; DX contains the most significant byte). You can determine the length of a file by setting CX:DX to 0, AL to 2, and calling this function. DX:AX returns the offset of the byte following the last byte in the file (size of the file in bytes).

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL not 0, 1, or 2
6	Handle not open

Macro Definition:

```
move_ptr  macro  handle,high,low,method
          mov    bx,handle
          mov    cx,high
          mov    dx,low
          mov    al,method
          mov    ah,42H
          int    21H
          endm
```

Example:

The following program prompts for a letter, converts it to its alphabetic sequence (A=1, B=2, etc.), then reads and displays the corresponding record from the file named alphabet.dat that is in the current directory on the disk in drive B. The file contains 26 records, each 28 bytes long.

```
file      db      "b:alphabet.dat",0
buffer    db       28 dup (?),"$"
prompt    db      "Enter letter: $"
crlf      db       0DH,0AH,"$"
handle    db       ?
record_length  dw  28
;
begin:    open_handle  file,0      ;See Function 3DH
          jc       error_open      ;Routine not shown
          mov      handle,ax       ;Save handle
get_char: display  prompt          ;See Function 09H
          read_kbd_and_echo        ;See Function 01H
          sub      al,41h          ;Convert to sequence
          mul      byte ptr record_length  ;Calculate offset
          move_ptr handle,0,ax,0   ;THIS FUNCTION
          jc       error_move      ;Routine not shown
          read_handle handle,buffer,record_length
          jc       error_read      ;Routine not shown
          cmp      ax,0            ;End of file?
          je       return          ;Yes, go home
          display  crlf            ;See Function 09H
          display  buffer          ;See Function 09H
```

```
          display  crlf            ;See Function 09H
          jmp      get_char        ;Get another character
```

Get/Set File Attributes (Function 43H)

Call:

```
AH = 43H
AL
   0 = Get attributes
   1 = Set attributes
CX (if AL=1)
   Attributes to be set
DS:DX
   Pointer to pathname
```

Return:

```
Carry set:
AX
   1 = Invalid function
   2 = File not found
   3 = Path not found
   5 = Access denied
Carry not set:
CX
   Attribute byte (if AL=0)
```

Comments:

Function 43H gets or sets the attributes of a file. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the pathname of a file. AL must specify whether to get or set the attribute (0=get, 1=set).

If AL is 0 (get the attribute), the attribute byte returns in CX. If AL is 1 (set the attribute), CX must contain the attributes to be set. The attributes are described under "File Attributes" earlier in this chapter.

You cannot change the VolumeID bit (08H) or the Subdirectory bit (10H) of the attribute byte with this function.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL not 0 or 1
2	File doesn't exist
3	Path invalid
5	Attribute in CX cannot be changed (Subdirectory or VolumeID).

Macro Definition:

```
change_attr  macro  path,action,attrib
             mov    dx,offset path
             mov    al,action
             mov    cx,attrib
             mov    ah,43H
```

```
            int    21H
            endm
```

Example:

The following program displays the attributes assigned to the file named report.asm that is in the current directory on the disk in drive B.

```
header    db      15 dup (20h),"Read-",0DH,0AH
          db     "Filename       Only      Hidden    "
          db     "System    Volume    Sub-Dir   Archive"
          db      0DH,0AH,0DH,0AH,"$"
path      db     "b:report.asm",3 dup (0),"$"
attribute dw      ?
blanks    db      9 dup (20h),"$"
;
begin:    change_attr  path,0,0  ;THIS FUNCTION
          jc      error_mode     ;Routine not shown
          mov     attribute,cx   ;Save attribute byte
          display header         ;See Function 09H
          display path           ;See Function 09H
          mov     cx,6           ;Check 6 bits (0-5)
          mov     bx,1           ;Start with bit 0
chk_bit:  test    attribute,bx   ;Is the bit set?
          jz      no_attr        ;No
          display_char "X"       ;See Function 02H
          jmp short  next_bit    ;Done with this bit
no_attr:  display_char  20h      ;See Function 02H
next_bit: display blanks         ;See Function 09H
          shl     bx,1           ;Move to next bit
          loop    chk_bit        ;Check it
```

IOCtl Data (Function 44H, Codes 0 and 1)

Call:

AH = 44H
AL
   0 = Get device data
   1 = Set device data
BX
   Handle
DX
   Device data (see text)

Return:

Carry set:
AX
   1 = Invalid function
   6 = Invalid handle
Carry not set:
DX
  Device data

Comments:

Function 44H, Codes 0 and 1, either gets or sets the data MS-DOS uses to control the device. AL must contain 0 to get the data or 1 to set it. BX

must contain the handle. If AL is 1, DH must contain 0.

The device-data word is specified or returned in DX. If bit 7 of the data is 1, the handle refers to a device and the other bits have the following meanings:

Table 1.23
MS-DOS Data Bit Values

Bit	Value	Meaning
Bit	Value	Meaning
0	1	Console input device
1	1	Console output device
2	1	Null device
3	1	Clock device
4	1	Reserved
5	1	Don't check for control characters
	0	Check for control characters
6	0	End of file on input
8-10		Reserved
11	1	Device understands open/close
Bit	Value	Meaning
12		Reserved
13	1	Device supports output until busy
14	1	Device can process control strings sent with Function 44H, Codes 2 and 3 (IOCtl character); bit can be read only, but not set
15		Reserved

You must set the reserved bits to zero.

The control characters referred to in the description of bit 5 are CONTROL-C, CONTROL-P, CONTROL-S, and CONTROL-Z. To read these characters as data, instead of as control characters, you must set bit 5 and use either Function 33H, CONTROL-C Check, or the MS-DOS break command to turn off CONTROL-C checking.

If bit 7 of DX is 0, the handle refers to a file and the other bits have the following meanings:

Bit	Value	Meaning
0-5		Drive number (0=A, 1=B, etc.)
6	0	The file has been written
8-15		Reserved

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL not 0 or 1, or AL is 1 but DH is not 0
6	Handle in BX not open or is invalid

Macro Definition:

```
ioctl_data macro  code,handle
           mov    bx,handle
           mov    al,code
           mov    ah,44H
           int    21H
           endm
```

Example:

The following program gets the device data for standard output, sets the bit that specifies not to check for control characters (bit 5), and then clears the bit.

```
get     equ         0
set     equ         1
stdout  equ         1
;
begin:  ioctl_data  get,stdout          ;THIS FUNCTION
        jc          error               ;routine not shown
        mov         dh,0                ;clear DH
        or          dl,20H              ;set bit 5
        ioctl_data  set,stdout          ;THIS FUNCTION
        jc          error               ;routine not shown
;
;  <control characters now treated as data, or "raw mode">
;
        ioctl_data  get,stdout          ;THIS FUNCTION
        jc          error               ;routine not shown
        mov         dh,0                ;clear DH
        and         dl,0DFH             ;clear bit 5
        ioctl_data  set,stdout          ;THIS FUNCTION
;
; <control characters now interpreted, or "cooked mode">
;
```

IOCtl Character (Function 44H, Codes 2 and 3)

Call:

AH = 44H
AL
   2 = Send control data
   3 = Receive control data
BX
   Handle
CX
   Bytes to read or write
DS:DX
   Pointer to buffer

Return:

Carry set:
AX
   1 = Invalid function
   6 = Invalid handle
Carry not set:
AX
   Bytes transferred

Comments:

Function 44H, Codes 2 and 3, sends or receives control data to or from a character device. AL must contain 2 to send data or 3 to receive. BX must contain the handle of a character device, such as a printer or serial port. CX must contain the number of bytes to be read or written. DX must contain the offset (to the segment address in DS) of the data buffer.

AX returns the number of bytes transferred. The device driver must support the IOCtl interface.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL not 2 or 3, or device cannot perform the specified function
6	Handle in BX not open or doesn't exist

Macro Definition:

```
ioctl_char  macro  code,handle,buffer
            mov    bx,handle
            mov    dx,offset buffer
            mov    al,code
            mov    ah,44H
            int    21H
            endm
```

Example:

No general example is applicable, since processing of IOCtl control data depends on the device being used, as well as the device driver.

IOCtl Block (Function 44H, Codes 4 and 5)

Call:

AH = 44H
AL
   4 = Send control data
   5 = Receive control data
BL
   Drive number (0=default, 1=A, etc.)
CX
   Bytes to read or write
DS:DX
   Pointer to buffer

Return:

Carry set:
AX
   1 = Invalid function
   5 = Invalid drive
Carry not set:
AX
   Bytes transferred

Comments:

Function 44H, Codes 4 and 5, sends or receives control data to or from a block device. AL must contain 4 to send data or 5 to receive. BL must contain the drive number (0=default, 1=A, etc.). CX must contain the number of bytes to be read or written. DX must contain the offset (to the segment address in DS) of the data buffer.

AX returns the number of bytes transferred. The device driver must support the IOCtl interface. To determine whether it does, use Function 44H, Code 0, to get the device data, and test bit 14; if the bit is set, the driver supports IOCtl.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL not 4 or 5, or device cannot perform the specified function
5	Number in BL not a valid drive number

Macro Definition:

```
ioctl_status macro  code,drive,buffer
             mov    bl,drive
             mov    dx,offset buffer
             mov    al,code
             mov    ah,44H
             int    21H
             endm
```

Example:

No general example is applicable, since processing of IOCtl control data depends on the device being used, as well as the device driver.

IOCtl Status (Function 44H, Codes 6 and 7)

Call:

AH = 44H
AL
   6 = Check input status
   7 = Check output status
BX
   Handle

Return:

Carry set:
AX
   1   = Invalid function
   5   = Access denied
   6   = Invalid handle
  13   = Invalid data
Carry not set:
AL
   00H   = Not ready
   0FFH   = Ready

Comments:

Function 44H, Codes 6 and 7, checks whether the file or device associated with a handle is ready. AL must contain 6 to check whether the handle is ready for input or 7 to check whether the handle is ready for output. BX must contain the handle.

AL returns the status:

Value	Meaning for Device	Meaning for Input File	Meaning for Output File
00H	Not ready	Pointer is at EOF	Ready
0FFH	Ready	Ready	Ready

An output file always returns ready, even if the disk is full.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL not 6 or 7
5	Access denied
6	Number in BX not a valid, open handle
13	Invalid data

Macro Definition:

```
ioctl_status  macro  code,handle
              mov    bx,handle
              mov    al,code
              mov    ah,44H
              int    21H
              endm
```

Example:

The following program displays a message that tells whether the file associated with handle 6 is ready for input or whether it is at end-of-file.

```
stdout      equ          1
;
message     db           "File is "
ready       db           "ready."
at_eof      db           "at EOF."
```

```
crlf        db           ODH,OAH
;
begin:      write_handle stdout,message,8   ;display message
            jc           write_error        ;routine not shown
            ioctl_status 6                  ;THIS FUNCTION
            jc           ioctl_error        ;routine not shown
            cmp          al,0               ;check status code
            jne          not_eof            ;file is ready
            write_handle stdout,at_eof,7    ;see Function 40H
            jc           write_error        ;routine not shown
            jmp          all_done           ;clean up & go home
not_eof:    write_handle stdout,ready,6     ;see Function 40H
all_done:   write_handle stdout,crlf,2      ;see Function 40H
            jc           write_error        ;routine not shown
```

IOCtl Is Changeable (Function 44H, Code 08H)

Call:

AH = 44H
AL = 08H
BL
   Drive number (0=default, 1=A, etc.)

Return:

Carry set:
AX
    1   = Invalid function
   15   = Invalid drive
Carry not set:
AX
   0 = Changeable
   1 = Not changeable

Comments:

Function 44H, Code 08H, checks whether a drive contains a removable or nonremovable disk. BL must contain the drive number (0=default, 1=A, etc.). AX returns 0 if the disk can be changed, 1 if it cannot.

This call lets a program determine whether to issue a message to change disks.

If there is an error, the carry flag (CF) is set and the error code returns in AX.

Code	Meaning
1	Device does not support this call
15	Number in BL not a valid drive number

When the call returns error 1 (because the driver doesn't support it), the caller asssumes that the driver cannot be changed.

Macro Definition:

```
ioctl_change  macro  drive
              mov    bl, drive
```

```
            mov    al, 08H
            mov    ah, 44H
            int    21H
            endm
```

Example:

The following program checks whether the current drive contains a removable disk. If not, processing continues; if so, the program prompts the user to replace the disk in the current drive.

```
stdout    equ        1
;
message   db        "Please replace disk in drive "
drives    db        "ABCD"
crlf      db         0DH,0AH
;
begin:    ioctl_change 0                  ;THIS FUNCTION
          jc           ioctl_error        ;routine not shown
          cmp          ax,0               ;current drive changeable?
          jne          continue           ;no, continue processing
          write_handle stdout,message,29  ;see Function 40H
          jc           write_error        ;routine not shown
          current_disk                    ;see Function 19H
          xor          bx,bx              ;clear index
          mov          bl,al              ;get current drive
          display_char drives[bx]         ;see Function 02H
          write_handle stdout,crlf,2      ;see Function 40H
          jc           write_error        ;routine not shown
continue:
;         (Further processing here)
```

IOCtl Is Redirected Block (Function 44H, Code 09H)

Call:

```
AH = 44H
AL = 09H
BL
   Drive number (0=default, 1=A, etc.)
```

Return:

```
Carry set:
AX
   1      = Invalid function code
  15      = Invalid drive number
Carry not set:
DX
   Device-attribute bits
```

Comments:

Function 44H, Code 09H, checks whether a drive letter refers to a drive on a Microsoft Networks workstation (local) or is redirected to a server (remote). BL must contain the drive number (0=default, 1=A, etc.).

If the block device is local, DX returns the attribute word from the device header. If the block device is remote, only bit 12 (1000H) is set;

the other bits are 0 (reserved).

An application program should not test bit 12, because applications should not make distinctions between local and remote files (or devices). Programs should be written so that they will be independent of the location of a device that has been removed.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	File sharing must be loaded to use this system call
15	Number in BL not a valid drive number

Macro Definition:

```
ioctl_rblock  macro  drive
              mov    bl, drive
              mov    al, 09H
              mov    ah, 44H
              int    21H
              endm
```

Example:

The following program checks whether drive B is local or remote and displays the appropriate message.

```
stdout    equ        1
;
message   db        "Drive B: is "
loc       db        "local."
rem       db        "remote."
crlf      db         0DH,0AH
;
begin:    write_handle stdout,message,12  ;display message
          jc           write_error        ;routine not shown
          ioctl_rblock 2                  ;THIS FUNCTION
          jc           ioctl_error        ;routine not shown
          test         dx,1000h           ;bit 12 set?
          jnz          not_loc            ;yes, it's remote
          write_handle stdout,loc,6       ;see Function 40H
          jc           write_error        ;routine not shown
          jmp          done
not_loc:  write_handle stdout,rem,7       ;see Function 40H
          jc           write_error        ;routine not shown
done:     write_handle stdout,crlf,2      ;see Function 40H
          jc           write_error        ;routine not shown
```

IOCtl Is Redirected Handle (Function 44H, Code 0AH)

Call:

AH = 44H
AL = 0AH
BX
   Handle

Return:

Carry set:
AX
   1 = Invalid function code
   6 = Invalid handle
Carry not set:
DX
   IOCtl bit field

Comments:

Function 44H, Code 0AH, checks whether a handle refers to a file or a device on a Microsoft Networks workstation (local) or is redirected to a server (remote). BX must contain the file handle. DX returns the IOCtl bit field; bit 15 is set if the handle refers to a remote file or device.

An application program should not test bit 15, because applications should not make distinctions between local and remote files (or devices). Programs should be written so that they will be independent of the location of a device that has been removed.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	Network must be loaded to use this system call
6	Handle in BX not a valid, open handle

Macro Definition:

```
ioctl_rhandle macro  handle
              mov    bx, handle
              mov    al, 0AH
              mov    ah, 44H
              int    21H
              endm
```

Example:

The following program checks whether handle 5 refers to a local or remote file or a device and displays the appropriate message.

```
stdout    equ        1
;
message   db        "Handle 5 is "
loc       db        "local."
rem       db        "remote."
crlf      db         0DH,0AH
;
begin:    write_handle stdout,message,12   ;display message
          jc           write_error         ;routine not shown
          ioctl_rhandle 5                  ;THIS FUNCTION
          jc           ioctl_error         ;routine not shown
          test         dx,8000h            ;bit 15 set?
          jnz          not_loc             ;yes, it's remote
          write_handle stdout,loc,6        ;see Function 40H
          jc           write_error         ;routine not shown
          jmp          done
not_loc:  write_handle stdout,rem,7        ;see Function 40H
```

```
          jc          write_error         ;routine not shown
done:     write_handle stdout,crlf,2      ;see Function 40H
          jc          write_error         ;routine not shown
```

IOCtl Retry (Function 44H, Code 0BH)

Call:

AH = 44H
AL = 0BH
DX
   Number of retries
CX
   Wait time

Return:

Carry set:
AX
   1 = Invalid function code
Carry not set:
   No error

Comments:

Function 44H, Code 0BH, specifies how many times MS-DOS should retry a disk operation that fails because of a file-sharing violation. DX must contain the number of retries. CX controls the pause between retries.

MS-DOS retries this type of disk operation three times, unless you use this system call to specify a different number. After the specified number of retries, MS-DOS issues Interrupt 24H (Critical-Error-Handler Address) for the requesting process.

The effect of the delay parameter in CX is machine-dependent because it specifies how many times MS-DOS should execute an empty loop. The actual time varies, depending on the processor and clock speed. You can determine the effect on your machine by using debug. Set the number of retries to 1 and then time several values of CX.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	File sharing must be loaded to use this system call

Macro Definition:

```
ioctl_retry  macro  retries, wait
             mov    dx, retries
             mov    cx, wait
             mov    al, 0BH
             mov    ah, 44H
             int    21H
             endm
```

Example:

The following program sets the number of sharing retries to 10 and specifies a delay of 1000 between retries.

```
begin:    ioctl_retry  10,1000          ;THIS FUNCTION
          jc           error            ;routine not shown
```

Generic IOCtl (for Handles) (Function 44H, Code 0CH)

Call:

AH = 44H
AL = 0CH
BX
    Handle
CH = 05H
    Category code (printer device)
CL
    Function (minor) code
DS:DX
    Pointer to data buffer

Return:

Carry set:
AX
    1 = Invalid function code
Carry not set:
    No error

Comments:

This call loads and selects code pages for devices on a per-device basis. It also sets or gets the output iteration count for a printer that supports "PRINT 'TIL BUSY."

The category code may be one of the following:

Code	Meaning
00	Unknown device
01	Serial printer
03	Console device
05	Parallel printer

The function code may be one of the following:

Code	Meaning
45H	Sets iteration count for printer
4AH	Select code page
4CH	Start prepare list
4DH	End prepare list
65H	Gets iteration count for printer
6AH	Query code page selected
6BH	Query code page prepare list

Note
  DS:DX points to a word that contains the new value for the total number

of output iterations performed before proceeding. Thus, DS:DX points to a word that contains the character iteration count for the "PRINT 'TIL BUSY" loop. This is the number of times the device driver will wait for the device to signal "ready" before acknowledging "Device busy."

.....

Macro Definition:

```
ioctl_handles       macro handle,function,category,buffer
                    mov ch,05H
                    mov cl,function
                    mov dx,offset buffer
                    mov bx,handle
                    mov ah,44H
                    mov al,0CH
                    int 21H
                    endm
```

Generic IOCtl (for Devices) (Function 44H, Code 0DH)

Call:

AH = 44H
AL = 0DH
BL
    Drive number
        (0 = default, 1 = A, etc.)
CH = 08H
    Category (major) code
CL
    Function (minor) code
DS:DX
    Pointer to parameter block -1

Return:

Carry set:
AX
    1 = Invalid function code
    2 = Invalid drive
Carry not set:
    No error

Comments:

The function code may be one of the following:

Code	Meaning
40	Set device parameters
41	Write track on logical device
42	Format track on logical device
60	Get device parameters
61	Read track on logical device
62	Verify track on logical device

.....
Note
  You must issue "Set Device Parameters" before you can read, write,

format, or verify a logical drive.

You should use the following procedure when you want to read, write, format, or verify a logical drive:

1. Save drive parameters using "Get Device Parameters."
2. Set desired drive parameters using "Set Device Parameters."
3. Perform the I/O operation.
4. Restore the original drive parameters using "Set Device Parameters."

Set Device Parameters (Function 44 0DH, CL=40H)

When CL=40H, the parameter block has the following field format:

BYTE	Special Functions
BYTE	Device Type
WORD	Device Attributes
WORD	Number of Cylinders
BYTE	Media Type
	Device BPB
	Track Layout

These fields have the following meanings:

Special Functions

Bit	Value	Meaning
Bit	Value	Meaning
0	0	The Device BPB (BIOS Parameter Block) field contains the new default BPB for this device. If a previous "Set Parameter Device" call set this bit, Build BPB returns the actual media BPB; otherwise, it returns the default BPB for the device.
	1	All subsequent Build BPB requests return the device BPB.
1	0	Read all fields of the parameter block.
	1	Ignore all fields of the parameter block except for the Track Layout field.
2	0	The sectors in the track may not all be the same size. (You should not use
Bit	Value	Meaning

#		be the same size. (You should not use this setting.)
	1	The sectors in the track are all the same size and the sector numbers range between 1 and the total number of sectors actually in the track. You should always set this bit.
3-7	0	These bits must be zero.

Device Type

This byte describes the physical device and is set by the device. When set, it has the following meanings:

Value	Meaning
0	320/360 KB
1	1.2 MB
2	720 KB
3	8-inch, single-density
4	8-inch, double-density
5	Hard disk
6	Tape drive
7	Other

Device Attributes

Bit	Value	Meaning
	0	The media is removable.
0	1	The media is not removable.
1	0	Disk change-line is not supported; (no door lock support).
	1	Disk change-line is supported; (door lock support).
2-7	0	These bits must be zero.

Number of Cylinders

This field indicates the maximum number of cylinders that the physical device can support. This information is set by the device.

Media Type

For drives that may contain different media, this field (which is device-dependent) indicates which media the drive expects.

For a 1.2 MB disk, bit zero has the following meaning:

Bit	Value	Meaning
0	0	Quad-density, 1.2 MB disk

	1	Double-density, 320/360 KB disk

The default media type is a quad-density 1.2 MB disk.

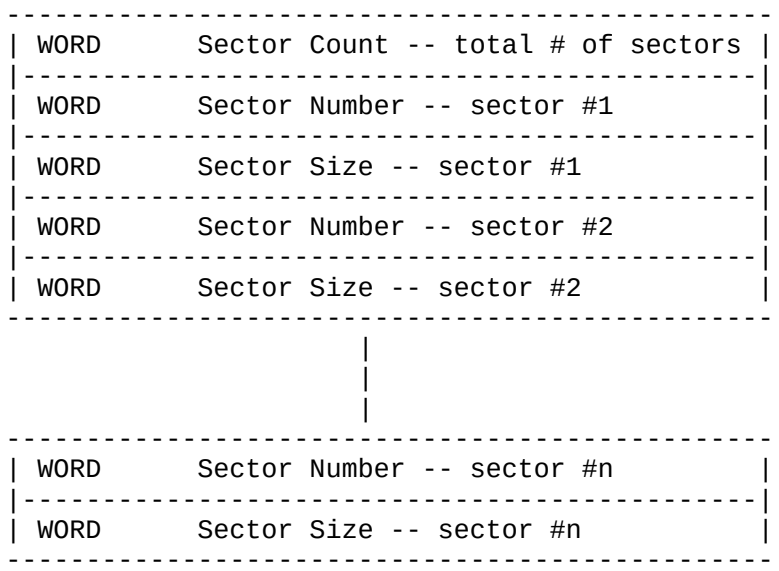
Device BPB

If bit 0 of the Special Functions field is clear, the BPB in this field is the new default BPB for the device.

If bit 0 of the Special Functions field is set, the device driver returns the BPB from this field for subsequent Build BPB requests.

Track Layout

This field contains a table of variable length for each logical device and indicates the expected layout of the sectors on the media track. The field has the following format:



The Sector Count field indicates the total number of sectors. Each sector number must be unique and in the range of 1 to sector count (n).

If bit 2 of the Special Functions field is set, all sector sizes must be the same.

Get Device Parameters (Function 440DH, CL=60H)

When CL=60H, the parameter block has the same field layout as for CL=40H. However, some of the fields have different meanings. These are described as follows:

Special Functions

Bit	Value	Meaning
0	0	Returns the default BPB for the device.
	1	Returns the BPB that Build BPB would return.
1-7	0	These bits must be zero.

Track Layout

The "Get Device Parameters" call does not use this field.

Read/Write Track on Logical Drive (Function 440D, CL=61H/CL=41H)

To write to a track on a logical drive, set CL=41H. To read a track on a logical drive, set CL=61H.

When CL=41H or 61H, the parameter block has the following format:

BYTE	Special Functions
WORD	Head
WORD	Cylinder
WORD	First Sector
WORD	Number of Sectors
DWORD	Transfer Address

These fields are described as follows:

Special Functions

This byte must be zero.

Head

This field contains the number of the head on which you perform the write or read.

Cylinder

This field contains the number of the cylinder on which you perform the write or read.

First Sector

This field contains the number of the first sector on which you perform the write or read. Sectors are numbered starting with zero, so the fourth sector is numbered 3.

Number of Sectors

This field contains the total number of sectors.

Transfer Address

This field contains the address for storing the data to be written or the data just read.

Format/Verify Track on Logical Drive (Function 440DH, CL=42/CL=62)

To format and verify a track on a logical drive, set CL=42H. To verify a track on a logical drive, set CL=62H.

When CL=42H or 62H, the parameter block has the following format:

BYTE	Special Functions
WORD	Head
WORD	Cylinder

These fields are described as follows:

Special Functions

This byte must be zero.

Head

This field contains the number of the head on which you perform the format or verify.

Cylinder

This field contains the number of the cylinder on which you perform the format or verify.

Get/Set IOCtl Drive Map (Function 44H, Codes 0EH and 0FH)

Call:

AH = 44H
AL
    OEH = Get logical drive map
    OFH = Set logical drive map
BX
    Drive number
        (0 = default, 1 = A, etc.)

Return:

Carry set:
AX
    1 = Invalid function code
    5 = Invalid drive
Carry not set:
AL = Logical drive mapped onto physical drive
     (= 0 if only one drive is
     assigned to this physical drive)

Comments:

MS-DOS 3.3 supports the mapping of multiple logical drives onto a single physical block device. Get IOCtl Drive Map lets you query the DOS about

which logical drive is currently mapped onto the corresponding physical device. Set IOCtl Drive Map alters the device that is currently mapped onto the physical device. These functions are only useful if there is more than one logical block device mapped onto a single physical device.

A possible use for these functions is with applications that want to disable the DOS prompt in order to place the correct floppy disk in the drive when accessing the other logical drive.

To detect whether a logical device currently owns the physical device it is mapped to, a program needs to check the value in AL after calling Function 440EH or 440FH (Get/Set IOCtl Drive Map).

Duplicate File Handle (Function 45H)

Call:

```
AH = 45H
BX
   Handle
```

Return:

```
Carry set:
AX
   4 = Too many open files
   6 = Invalid handle
Carry not set:
AX
   New handle
```

Comments:

Function 45H creates an additional handle for a file. BX must contain the handle of an open file.

MS-DOS returns the new handle in AX. The new handle refers to the same file as the handle in BX, with the file pointer at the same position.

After you use this function request, moving the read/write pointer of either handle also moves the pointer for the other handle. You usually use this function request to redirect standard input (handle 0) and standard output (handle 1). For a description of standard input, standard output, and the advantages and techniques of manipulating them, see Software Tools by Brian W. Kernighan and P.J. Plauger (Addison-Wesley Publishing Co., 1976).

If there is an error, the carry flag (CF) is set and the error code returns in AX:

```
Code     Meaning
.........
4        Too many open files (no handle available)
6        Handle not open or is invalid
```

Macro Definition:

```
xdup  macro  handle
      mov    bx,handle
```

```
      mov    ah,45H
      int    21H
      endm
```

Example:

The following program redirects standard output (handle 1) to a file named dirfile, invokes a second copy of command.com to list the directory (which writes the directory to dirfile), and then restores standard input to handle 1.

```
pgm_file  db    "command.com",0
cmd_line  db    9,"/c dir /w",0dH
parm_blk  db    14 dup (0)
path            db  "dirfile",0
dir_file        dw      ?         ; For handle
sav_stdout dw   ?                 ; For handle
;
begin:    set_block  last_inst    ; See Function 4AH
          jc      error_setblk    ; Routine not shown
          create_handle  path,0   ; See Function 3CH
          jc      error_create    ; Routine not shown
          mov     dir_file,ax     ; Save handle
          xdup    1               ; THIS FUNCTION
          jc      error_xdup      ; Routine not shown
          mov     sav_stdout,ax   ; Save handle
          xdup2   dir_file,1      ; See Function 46H
          jc      error_xdup2     ; Routine not shown
          exec    pgm_file,cmd_line,parm_blk ; See Function 4BH
          jc      error_exec      ; Routine not shown
          xdup2   sav_stdout,1    ; See Function 46H
          jc      error_xdup2     ; Routine not shown
          close_handle sav_stdout ; See Function 3EH
          jc      error_close     ; Routine not shown
          close_handle dir_file   ; See Function 3EH
          jc      error_close     ; Routine not shown
```

Force Duplicate File Handle (Function 46H)

Call:

AH = 46H
BX
   Handle
CX
   Second handle

Return:

Carry set:
AX
   4 = Too many open files
   6 = Invalid handle
Carry not set:
   No error

Comments:

Function 46H forces a specified handle to refer to the same file as

a second handle already associated with an open file. BX must contain the handle of the open file; CX must contain the second handle.

On return, the handle in CX now refers to the same file at the same position as the handle in BX. If the file referred to by the handle in CX was open at the time of the call, this function closes it.

After you use this call, moving the read/write pointer of either handle also moves the pointer for the other handle. Normally, you would use this function request to redirect standard input (handle 0) and standard output (handle 1). For a description of standard input, standard output, and the advantages and techniques of manipulating them, see Software Tools by Brian W. Kernighan and P.J. Plauger (Addison-Wesley Publishing Co., 1976).

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
4	Too many open files (no handle available)
6	Handle not open or is invalid

Macro Definition:

```
xdup2  macro  handle1,handle2
       mov    bx,handle1
       mov    cx,handle2
       mov    ah,46H
       int    21H
       endm
```

Example:

The following program redirects standard output (handle 1) to a file named dirfile, invokes a second copy of command.com to list the directory (which writes the directory to dirfile), and then restores standard input to handle 1.

```
pgm_file  db    "command.com",0
cmd_line  db    9,"/c dir /w",0dH
parm_blk  db    14 dup (0)
path            db  "dirfile",0
dir_file        dw      ?         ; For handle
sav_stdout dw   ?                 ; For handle
;
begin:    set_block  last_inst    ; See Function 4AH
          jc      error_setblk    ; Routine not shown
          create_handle  path,0   ; See Function 3CH
          jc      error_create    ; Routine not shown
          mov     dir_file,ax     ; Save handle
          xdup    1               ; See Function 45H
          jc      error_xdup      ; Routine not shown
          mov     sav_stdout,ax   ; Save handle
          xdup2   dir_file,1      ;
          jc      error_xdup2     ; Routine not shown
          exec    pgm_file,cmd_line,parm_blk ; See Function 4BH
          jc      error_exec      ; Routine not shown
          xdup2   sav_stdout,1    ; THIS FUNCTION
          jc      error_xdup2     ; Routine not shown
          close_handle sav_stdout ; See Function 3EH
          jc      error_close     ; Routine not shown
          close_handle dir_file   ; See Function 3EH
```

```
          jc      error_close     ; Routine not shown
```

Get Current Directory (Function 47H)

Call:

```
AH = 47H
DS:SI
   Pointer to 64-byte memory area
DL
   Drive number
      (0 = default, 1 = A)
```

Return:

```
Carry set:
AX
   15 = Invalid drive number
Carry not set:
   No error
```

Comments:

Function 47H returns the pathname of the current directory on a specified drive. DL must contain a drive number (0=default, 1=A, etc.). SI must contain the offset (from the segment address in DS) of a 64-byte memory area.

MS-DOS places an ASCIZ string in the memory area, consisting of the path (starting from the root directory) of the current directory for the drive specified in DL. The string does not begin with a backslash and does not include the drive letter.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

```
Code     Meaning
.........
15       Number in DL not a valid drive number
```

Macro Definition:

```
get_dir  macro   drive,buffer
         mov     dl,drive
         mov     si,offset buffer
         mov     ah,47H
         int     21H
         endm
```

Example:

The following program displays the current directory that is on the disk in drive B.

```
disk        db      "b:
buffer      db       64 dup (?)
;
begin:      get_dir  2,buffer       ;THIS FUNCTION
```

```
            jc       error_dir      ;Routine not shown
            display  disk           ;See Function 09H
            display_asciz  buffer   ;See end of chapter
```

Allocate Memory (Function 48H)

Call:

AH = 48H
BX
  Paragraphs of memory requested

Return:

Carry set:
AX
  7 = Memory-control blocks damaged
  8 = Insufficient memory
BX
  Paragraphs of memory available
Carry not set:
AX
  Segment address of allocated memory

Comments:

Function 48H tries to allocate the specified amount of memory to the current process. BX must contain the number of paragraphs of memory (one paragraph is 16 bytes).

If sufficient memory is available to satisfy the request, AX returns the segment address of the allocated memory (the offset is 0). If sufficient memory is not available, BX returns the number of paragraphs of memory in the largest available block.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
7	Memory-control blocks damaged (a user program changed memory that doesn't belong to it)
8	Not enough free memory to satisfy the request

Macro Definition:

```
allocate_memory  macro   bytes
                 mov     bx,bytes
                 mov     cl,4
                 shr     bx,cl
                 inc     bx
                 mov     ah,48H
                 int     21H
                 endm
```

Example:

The following program opens the file named textfile.asc, calculates its size with Function 42H (Move File Pointer), allocates a block of memory the size of the file, reads the file into the allocated memory block, and then frees the allocated memory.

```
path      db      "textfile.asc",0
msg1      db      "File loaded into allocated memory block.",
                   0DH,0AH
msg2      db      "Allocated memory now being freed
                   (deallocated).",0DH,0AH
handle    dw       ?
mem_seg   dw       ?
file_len  dw       ?
;
begin:    open_handle  path,0
          jc       error_open         ;Routine not shown
          mov      handle,ax          ;Save handle
          move_ptr handle,0,0,2       ;See Function 42H
          jc       error_move         ;Routine not shown
          mov      file_len,ax        ;Save file length
          set_block  last_inst        ;See Function 4AH
          jc       error_setblk       ;Routine not shown
          allocate_memory  file_len   ;THIS FUNCTION
          jc       error_alloc        ;Routine not shown
          mov      mem_seg,ax         ;Save address of new memory
          move_ptr handle,0,0,0       ;See Function 42H
          jc       error_move         ;Routine not shown
          push     ds                 ;Save DS
          mov      ax,mem_seg         ;Get segment of new memory
          mov      ds,ax              ;Point DS at new memory
          read_handle  cs:handle,0,cs:file_len ;Read file into new memory
          pop      ds                 ;Restore DS
          jc       error_read         ;Routine not shown
;         (CODE TO PROCESS FILE GOES HERE)
          write_handle stdout,msg1,42 ;See Function 40H
          jc       write_error        ;Routine not shown
          free_memory  mem_seg        ;See Function 49H
          jc       error_freemem      ;Routine not shown
          write_handle stdout,msg2,49 ;See Function 40H
          jc       write_error        ;Routine not shown
```

Free Allocated Memory (Function 49H)

Call:

AH = 49H
ES
   Segment address of memory to be
   freed

Return:

Carry set:
AX
   7 = Memory-control blocks damaged
   9 = Incorrect segment
Carry not set:
   No error

Comments:

Function 49H frees (makes available) a block of memory previously allocated with Function 48H (Allocate Memory). ES must contain the segment address of the memory block to be freed.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
7	Memory-control blocks damaged (a user program changed memory that didn't belong to it)
9	Memory pointed to by ES was not allocated with Function 48H

Macro Definition:

```
free_memory  macro     seg_addr
             mov       ax,seg_addr
             mov       es,ax
             mov       ah,49H
             int       21H
             endm
```

Example:

The following program opens a file named textfile.asc, calculates its size with Function 42H (Move File Pointer), allocates a block of memory the size of the file, reads the file into the allocated memory block, and then frees the allocated memory.

```
path      db      "textfile.asc",0
msg1      db      "File loaded into allocated memory block.",
                   0DH,0AH
msg2      db      "Allocated memory now being freed
                   (deallocated).",0DH,0AH
handle    dw       ?
mem_seg   dw       ?
file_len  dw       ?
;
begin:    open_handle  path,0
          jc       error_open         ;Routine not shown
          mov      handle,ax          ;Save handle
          move_ptr handle,0,0,2       ;See Function 42H
          jc       error_move         ;Routine not shown
          mov      file_len,ax        ;Save file length
          set_block  last_inst        ;See Function 4AH
          jc       error_setblk       ;Routine not shown
          allocate_memory  file_len   ;See Function 48H
          jc       error_alloc        ;Routine not shown
          mov      mem_seg,ax         ;Save address of new memory
          mov_ptr  handle,0,0,0       ;See Function 42H
          jc       error_move         ;Routine not shown
          push     ds                 ;Save DS
          mov      ax,mem_seg         ;Get segment of new memory
          mov      ds,ax              ;Point DS at new memory
          read_handle  handle,code,file_len ;Read file into new memory
;
          pop      ds                 ;Restore DS
          jc       error_read         ;Routine not shown
;         (CODE TO PROCESS FILE GOES HERE)
          write_handle stdout,msg1,42 ;See Function 40H
```

```
          jc       write_error        ;Routine not shown
          free_memory  mem_seg        ;THIS FUNCTION
          jc       error_freemem      ;Routine not shown
          write_handle stdout,msg2,49 ;See Function 40H
          jc       write_error        ;Routine not shown
```

Set Block (Function 4AH)

Call:

AH = 4AH
BX
   Paragraphs of memory
ES
   Segment address of memory area

Return:

Carry set:
AX
   7 = Memory-control blocks damaged
   8 = Insufficient memory
   9 = Incorrect segment
BX
   Paragraphs of memory available
Carry not set:
   No error

Comments:

Function 4AH changes the size of a memory-allocation block. ES must contain the segment address of the memory block. BX must contain the new size of the memory block, in paragraphs (one paragraph is 16 bytes).

MS-DOS attempts to change the size of the memory block. If the call fails on a request to increase memory, BX returns the maximum size (in paragraphs) to which the block can be increased.

Since MS-DOS allocates all available memory to a .com program, you would use this call most often to reduce the size of a program's initial memory-allocation block.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
7	Memory-control blocks destroyed (a user program changed memory that didn't belong to it)
8	Not enough free memory to satisfy the request
9	Wrong address in ES (the memory block it points to cannot be modified with Set Block)

The following macro shrinks the initial memory-allocation block of a .com program. It takes as a parameter the offset of the first byte following the last instruction of a program (LAST_INST in the sample programs), uses it to calculate the number of paragraphs in the program, and then adds 17 to the result: one to round up and 16 to set aside 256

bytes for a stack. It then sets up SP and BP to point to this stack.

Macro Definition:

```
set_block  macro   last_byte
           mov     bx,offset last_byte
           mov     cl,4
           shr     bx,cl
           add     bx,17
           mov     ah,4AH
           int     21H
           mov     ax,bx
           shl     ax,cl
           dec     ax
           mov     sp,ax
           mov     bp,sp
           endm
```

Example:

The following program invokes a second copy of command.com and executes a dir (directory) command.

```
pgm_file  db      "command.com",0
cmd_line  db       9,"/c dir /w",0DH
parm_blk  db       14 dup (?)
reg_save  db       10 dup (?)
;
begin: set_block  last_inst                      ;THIS FUNCTION
       exec       pgm_file,cmd_line,parm_blk,0  ;See Function 4BH
```

Load and Execute Program (Function 4BH, Code 00H)

Call:

```
AH = 4BH
AL = 00H
DS:DX
   Pointer to pathname
ES:BX
   Pointer to parameter block
```

Return:

```
Carry set:
AX
   1      = Invalid function
   2      = File not found
   3      = Path not found
   4      = Too many open files
   5      = Access denied
   8      = Insufficient memory
  10      = Bad environment
  11      = Bad format
Carry not set:
  No error
```

Comments:

Function 4BH, Code 00H, loads and executes a program. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the drive and pathname of an executable program file. BX must contain the offset (from the segment address in ES) of a parameter block. AL must contain 0.

There must be enough free memory for MS-DOS to load the program file. MS-DOS allocates all available memory to a program when it loads it, so you must free some memory with Function 4AH (Set Block) before using this function request to load and execute another program. Unless you or MS-DOS needs the memory for some other purpose, you should shrink the memory to the minimum amount required by the current process before issuing this request.

MS-DOS creates a Program Segment Prefix for the program being loaded and sets the terminate and CONTROL-C addresses to the instruction that immediately follows the call to Function 4BH in the invoking program.

The parameter block consists of four addresses:

Table 1.24
Contents of the Parameter Block

Offset (Hex)	Length (Bytes)	Description
00	2 (word)	Segment address of the environment to be passed; 00H means copy the parent program's environment.
02	4 (dword)	Segment: Offset of command line to be placed at offset 80H of the new Program Segment Prefix. Must be a correctly-formed command line no longer than 128 bytes.
06	4 (dword)	Segment: Offset of FCB to be placed at offset 5CH of the new Program Segment Prefix (the Program Segment Prefix is described in Chapter 4 "MS-DOS Control Blocks and Work Areas")
0A	4 (dword)	Segment: Offset of FCB to be placed at offset 6CH of the new Program Segment Prefix

Offset (Hex) | Length (Bytes) | Description

All open files of a program are available to the newly loaded program, giving the parent program control over the definition of standard input, output, auxiliary, and printer devices. For example, a program could write a series of records to a file, open the file as standard input, open a second file as standard output, and then use Function 4BH, Code 00H (Load and Execute Program) to load and execute a program that takes its input from standard input, sorts records, and writes to standard output.

The loaded program also receives an environment, a series of ASCIZ

strings of the form parameter=value (for example, verify = on). The environment must begin on a paragraph boundary, be less than 32K bytes long, and end with a byte of 00H (that is, the final entry consists of an ASCIZ string followed by two bytes of 00H). Following the last byte of zeros is a set of initial arguments passed to a program containing a word count followed by an ASCIZ string. If the call finds the file in the current directory, the ASCIZ string contains the drive and pathname of the executable program as passed to Function 4BH. If the call finds the file in the path, it concatenates the filename with the path information. (A program may use this area to determine whence it was loaded.) If the word-environment address is 0, the loaded program either inherits a copy of the parent program's environment or receives a new environment built for it by the parent.

Place the segment address of the environment at offset 2CH of the new Program Segment Prefix. To build an environment for the loaded program, put it on a paragraph boundary and place the segment address of the environment in the first word of the parameter block. To pass a copy of the parent's environment to the loaded program, put 00H in the first word of the parameter block.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL not 0 or 3
2	Program file not found
3	Path invalid or not found
4	Too many open files (no handle available)
5	Directory full, a directory with the same name exists, or a file with the same name exists
8	Not enough memory to load the program
10	Environment appears longer than 32K
11	Program file is an .exe file that contains internally inconsistent information

Executing Another Copy of Command.com

Since command.com builds pathnames, searches command paths for program files, and relocates .exe files, the simplest way to load and execute another program is to load and execute an additional copy of command.com, passing it a command line that includes the /c switch, which invokes the .com or .exe file.

This action requires 17K bytes of available memory, so a program that does it should be sure to shrink its initial memory-allocation block with Function 4AH (Set Block). The format of a command line that contains the /c switch:

length,/c command,0DH

Length is the length of the command line, counting the length byte but not the ending carriage-return (0DH).

Command is any valid MS-DOS command.

0DH is a carriage-return character.

If a program executes another program directly--naming it as the program file to Function 4BH instead of command.com--it must perform all the processing normally done by command.com.

Macro Definition:

```
exec  macro  path,command,parms
      mov    dx,offset path
      mov    bx,offset parms
      mov    word ptr parms[02H],offset command
      mov    word ptr parms[04H],cs
      mov    word ptr parms[06H],5CH
      mov    word ptr parms[08H],es
      mov    word ptr parms[0AH],6CH
      mov    word ptr parms[0CH],es
      mov    al,0
      mov    ah,4BH
      int    21H
      endm
```

Example:

The following program invokes a second copy of command.com and executes a dir (directory) command by using the /w (wide) switch:

```
pgm_file  db      "command.com",0
cmd_line  db       9,"/c dir /w",0DH
parm_blk  db       14 dup (?)
reg_save  db       10 dup (?)
;
begin:
   set_block  last_inst                    ;See Function 4AH
   exec       pgm_file,cmd_line,parm_blk,0 ;THIS FUNCTION
```

Load Overlay (Function 4BH, Code 03H)

Call:

```
AH = 4BH
AL = 03H
DS:DX
   Pointer to pathname
ES:BX
   Pointer to parameter block
```

Return:

```
Carry set:
AX
   1      = Invalid function
   2      = File not found
   3      = Path not found
   4      = Too many open files
   5      = Access denied
   8      = Insufficient memory
  10      = Bad environment
```

Carry not set:
  No error

Comments:

Function 4BH, Code 03H, loads a program segment (overlay). DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the drive and pathname of the program file. BX must contain the offset (from the segment address in ES) of a parameter block. AL must contain 3.

MS-DOS assumes that since the invoking program is loading into its own address space, it requires no free memory. This call does not create a Program Segment Prefix.

The parameter block is four bytes long:

Table 1.25
Contents of the Parameter Block

Offset (Hex)	Length (Bytes)	Description
Offset (Hex)	Length (Bytes)	Description
00	2 (word)	Segment address where program is to be loaded
02	2 (word)	Relocation factor; usually the same as the first word of the parameter block (for a description of an .exe file and of relocation, see Chapter 6, ".Exe File Structure and Loading.")

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL not 00H or 03H
2	Program file not found
3	Path invalid or not found
4	Too many open files (no handle available)
5	Directory is full, a directory with the same name exists, or a file with the same name exists
8	Not enough memory to load the program
10	Environment appears longer than 32K

Macro Definition:

```
exec_ovl  macro  path,parms,seg_addr
          mov    dx,offset path
          mov    bx,offset parms
          mov    parms,seg_addr
```

```
          mov    parms[02H],seg_addr
          mov    al,3
          mov    ah,4BH
          int    21H
          endm
```

Example:

The following program opens a file named textfile.asc, redirects standard input to that file, loads more.com as an overlay, and calls an overlay named bit.com, which reads textfile.asc as standard input. The overlay must establish its own addressability and end with a FAR return.

```
stdin     equ       0
;
file      db    "TEXTFILE.ASC",0
cmd_file  db    "\bit.com",0
parm_blk  dw     4 dup (?)
overlay   label  dword
          dw     0
handle    dw     ?
new_mem   dw     ?
;
begin:    set_block   last_inst            ;see Function 4AH
          jc          setblock_error       ;routine not shown
          allocate_memory  2000            ;see Function 48H
          jc          allocate_error       ;routine not shown
          mov         new_mem,ax           ;save seg of memory
          open_handle file,0               ;see Function 3DH
          jc          open_error           ;routine not shown
          mov         handle,ax            ;save handle
          xdup2       handle,stdin         ;see Function 45H
          jc          dup2_error           ;routine not shown
          close_handle handle              ;see Function 3EH
          jc          close_error          ;routine not shown
          mov         ax,new_mem           ;addr of new memory
          exec_ovl cmd_file,parm_blk,ax    ;THIS FUNCTION
          jc          exec_error           ;routine not shown
          call        overlay              ;call the overlay
          free_memory new_mem              ;see Function 49H
          jc          free_error           ;routine not shown
;
```

End Process (Function 4CH)

Call:

AH = 4CH
AL
   Return code

Return:

None

Comments:

Function 4CH terminates a process and returns to MS-DOS. AL contains a return code that can be retrieved by the parent process with Function 4DH

(Get Return Code of Child Process) or the if command, using errorlevel.

MS-DOS closes all open handles, ends the current process, and returns control to the invoking process.

This function request doesn't require CS to contain the segment address of the Program Segment Prefix. You should use it to end a program (rather than Interrupt 20H or a jump to location 0) unless your program must be compatible with MS-DOS versions before 2.0.

.....
Note
  If you use file sharing, you must remove all locks issued by this
  process or the DOS will be in an uncertain state.
.....

Macro Definition:

```
end_process  macro  return_code
             mov    al,return_code
             mov    ah,4CH
             int    21H
             endm
```

Example:

The following program displays a message and returns to MS-DOS with a return code of 8. It uses only the opening portion of the sample program skeleton shown at the beginning of this chapter.

```
message   db     "Displayed by FUNC_4CH example",0DH,0AH,"$"
;
begin:    display      message   ;See Function 09H
          end_process  8         ;THIS FUNCTION
code      ends
          end          code
```

Get Return Code of Child Process (Function 4DH)

Call:

AH = 4DH

Return:

AX
   Return code

Comments:

Function 4DH retrieves the return code specified when a child process terminates via either Function 31H (Keep Process) or Function 4CH (End Process). The code returns in AL. AH returns a code that specifies why the program ended:

Code	Meaning
0	Normal termination

```
1        Terminated by CONTROL-C
2        Critical device error
3        Function 31H (Keep Process)
```

This call can retrieve the exit code only once.

Macro Definition:

```
ret_code  macro
          mov    ah,4DH
          int    21H
          endm
```

Example:

No example is included for this function request, because the meaning of a return code varies.

Find First File (Function 4EH)

Call:

```
AH = 4EH
DS:DX
   Pointer to pathname
CX
   Attributes to match
```

Return:

```
Carry set:
AX
   2      = File not found
   3      = Path not found
  18      = No more files
Carry not set:
   No error
```

Comments:

Function 4EH searches the current or specified directory for the first entry that matches the specified pathname. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies the pathname, which can contain wildcard characters. CX must contain the attribute to be used in searching for the file, as described in Section 1.5.5, "File Attributes."

If the attribute field is hidden file, system file, or subdirectory entry (02H, 04H, or 10H), or any combination of these values, all normal file entries are also searched. To search all directory entries except the volume label, set the attribute byte to 16H (hidden file, system file, and directory entry).

If this function finds a directory entry that matches the name and attribute, it fills the current DTA as follows:

Table 1.26

```
.............k
```

Offset	Length	Description
00H	21	Reserved for subsequent Function 4FH (Find Next File)
15H	1	Attribute found
16H	2	Time file was last written
18H	2	Date file was last written
1AH	2	Low word of file size
1CH	2	High word of file size
1EH	13	Name and extension of the file, followed by 00H. All blanks are removed; if there is an extension, it is preceded by a period. (Volume labels include a period after the eighth character.)

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	Specified file invalid or doesn't exist
3	Specified path invalid or doesn't exist
18	No matching directory entry found

Macro Definition:

```
find_first_file  macro  path,attrib
                 mov    dx,offset path
                 mov    cx,attrib
                 mov    ah,4EH
                 int    21H
                 endm
```

Example:

The following program displays a message that specifies whether a file named report.asm exists in the current directory on the disk in drive B.

```
yes         db      "File exists.",0DH,0AH,"$"
no          db      "File does not exist.",0DH,0AH,"$"
path        db      "b:report.asm",0
buffer      db       43 dup (?)
;
begin:      set_dta  buffer           ;See Function 1AH
            find_first_file  path,0   ;THIS FUNCTION
            jc       error_findfirst  ;Routine not shown
            cmp      al,12H           ;File found?
            je       not_there        ;No
            display  yes              ;See Function 09H
            jmp      return           ;All done
not_there:  display  no               ;See Function 09H
```

Find Next File (Function 4FH)

Call:

AH = 4FH

Return:

Carry set:
AX
  18 = No more files
Carry not set:
   No error

Comments:

Function 4FH searches for the next directory entry that matches the name and attributes specified in a previous Function 4EH (Find First File). The current DTA must contain the information filled in by Function 4EH (Find First File).

If the function finds a matching entry, it fills the current DTA just as it did for Find First File (see Function 4EH (Find First File)).

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	Specified path invalid or doesn't exist
18	No matching directory entry found

Macro Definition:

```
find_next_file  macro
                mov    ah,4FH
                int    21H
                endm
```

Example:

The following program displays the number of files contained in the current directory on the disk in drive B.

```
message     db      "No files",0DH,0AH,"$"
files       dw       ?
path        db      "b:*.*",0
buffer      db       43 dup (?)
;
begin:      set_dta  buffer             ;See Function 1AH
            find_first_file  path,0      ;See Function 4EH
            jc       error_findfirst    ;Routine not shown
            cmp      al,12H             ;Directory empty?
            je       all_done           ;Yes, go home
            inc      files              ;No, bump file counter
search_dir: find_next_file              ;THIS FUNCTION
            jc       error_findnext     ;Routine not shown
            cmp      al,12H             ;Any more entries?
            je       done               ;No, go home
            inc      files              ;Yes, bump file counter
            jmp      search_dir         ;And check again
```

```
done:       convert  files,10,message  ;See end of chapter
all_done:   display  message           ;See Function 09H
```

Get Verify State (Function 54H)

Call:

AH = 54H

Return:

AL
   0 = No verify after write
   1 = Verify after write

Comments:

Function 54H checks whether MS-DOS verifies write operations to disk files. The status returns in AL: 0 if verify is off, 1 if verify is on.

You can set the verify status with Function 2EH (Set/Reset Verify Flag).

Macro Definition:

```
get_verify  macro
            mov    ah,54H
            int    21H
            endm
```

Example:

The following program displays the verify status:

```
message   db     "Verify ","$"
on        db     "on.",0DH,0AH,"$"
off       db     "off.",0DH,0AH,"$"
;
begin:    display message      ;See Function 09H
          get_verify           ;THIS FUNCTION
          cmp     al,0         ;Is flag off?
          jg      ver_on       ;No, it's on
          display off          ;See Function 09H
          jmp     return       ;Go home
ver_on:   display on           ;See Function 09H
```

Change Directory Entry (Function 56H)

Call:

AH = 56H
DS:DX
   Pointer to pathname
ES:DI
   Pointer to second pathname

Return:

Carry set:
AX
   2   = File not found
   3   = Path not found
   5   = Access denied
  17   = Not same device
Carry not set:
   No error

Comments:

Function 56H renames a file by changing its directory entry. DX must contain the offset (from the segment address in DS) of an ASCIZ string that contains the pathname of the entry to be changed. DI must contain the offset (from the segment address in ES) of an ASCIZ string that contains a second pathname to which the first is to be changed.

If a directory entry for the first pathname exists, it is changed to the second pathname.

The directory paths need not be the same; in effect, you can move the file to another directory by renaming it. You cannot use this function request to copy a file to another drive, however; if the second pathname specifies a drive, the first pathname must specify or default to the same drive.

You cannot use this function request to rename an open file, a hidden file, a system file, or a subdirectory, because it may corrupt your disk.

If there is an error, the carry flag (CF) is set and the error code returns in AX.

Code	Meaning
2	One of files is invalid or not open
3	One of paths is invalid or not open
5	First pathname specifies a directory, second pathname specifies an existing file; or second directory entry could not be opened
17	Both files not on the same drive

Macro Definition:

```
rename_file  macro  old_path,new_path
             mov    dx,offset old_path
             push   ds
             pop    es
             mov    di,offset new_path
             mov    ah,56H
             int    21H
             endm
```

Example:

The following program prompts for the name of a file and a new name, then renames the file.

```
prompt1   db     "Filename: $"
prompt2   db     "New name: $"
old_path  db      15,?,15 dup (?)
new_path  db      15,?,15 dup (?)
crlf      db      0DH,0AH,"$"
;
begin:    display prompt1                       ;See Function 09H
          get_string  15,old_path               ;See Function 0AH
          xor     bx,bx                         ;To use BL as index
          mov     bl,old_path[1]                ;Get string length
          mov     old_path[bx+2],0              ;Make an ASCIZ string
          display crlf                          ;See Function 09H
          display prompt2                       ;See Function 09H
          get_string  15,new_path               ;See Function 0AH
          xor     bx,bx                         ;To use BL as index
          mov     bl,new_path[1]                ;Get string length
          mov     new_path[bx+2],0              ;Make an ASCIZ string
          display crlf                          ;See Function 09H
          rename_file old_path[2],new_path[2]  ;THIS FUNCTION
          jc      error_rename                  ;Routine not shown
```

Get/Set Date/Time of File(Function 57H)

Call:

AH = 57H
AL = Function code
   0 = Get date and time
   1 = Set date and time
BX
   Handle
CX (if AL = 1)
   Time to be set
DX (if AL = 1)
   Date to be set

Return:

Carry set:
AX
   1 = Invalid function
   6 = Invalid handle
Carry not set:
CX (if AL = 0)
   Time file last written
DX (if AL = 0)
   Date file last written

Comments:

Function 57H gets or sets the time and date when a file was last written. To get the time and date, AL must contain 0; the time and date return in CX and DX. To set the time and date, AL must contain 1; CX and DX must contain the time and date. BX must contain the file handle. The time and date are in the form described in "Fields of the FCB" in Section 1.9.1.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code   Meaning

```
.........
1       AL not 0 or 1
6       Handle in BX invalid or not open
```

Macro Definition:

```
get_set_date_time macro  handle,action,time,date
                  mov    bx,handle
                  mov    al,action
                  mov    cx,word ptr time
                  mov    dx,word ptr date
                  mov    ah,57H
                  int    21H
                  endm
```

Example:

The following program gets the date of a file named report.asm in the current directory on the disk in drive B, increments the day, increments the month and/or year, if necessary, and sets the new date of the file.

```
month     db      31,28,31,30,31,30,31,31,30,31,30,31
path      db     "b:report.asm",0
handle    dw      ?
time      db      2 dup (?)
date      db      2 dup (?)
;
begin:    open_handle  path,0                  ;See Function 3DH
          mov     handle,ax                    ;Save handle
          get_set_date_time handle,0,time,date ;THIS FUNCTION
          jc      error_time                   ;Routine not shown
          mov     word ptr time,cx             ;Save time
          mov     word ptr date,dx             ;Save date
          convert_date  date[-24]              ;See end of chapter
          inc     dh                           ;Increment day
          xor     bx,bx                        ;To use BL as index
          mov     bl,dl                        ;Get month
          cmp     dh,month[bx-1]               ;Past last day?
          jle     month_ok                     ;No, go home
          mov     dh,1                         ;Yes, set day to 1
          inc     dl                           ;Increment month
          cmp     dl,12                        ;Is it past December?
          jle     month_ok                     ;No, go home
          mov     dl,1                         ;Yes, set month to 1
          inc     cx                           ;Increment year
month_ok: pack_date  date                      ;See end of chapter
          get_set_date_time handle,1,time,date ;THIS FUNCTION
          jc      error_time                   ;Routine not shown
          close_handle  handle                 ;See Function 3EH
          jc      error_close                  ;Routine not shown
```

Get/Set Allocation Strategy (Function 58H)

Call:

```
AH = 58H
AL
   0 = Get strategy
   1 = Set strategy
BX (AL = 1)
```

0 = First fit
1 = Best fit
2 = Last fit

Return:

Carry set:
AX
1 = Invalid function code
Carry not set:
AX (AL = 0)
0 = First fit
1 = Best fit
2 = Last fit

Comments:

Function 58H gets or sets the strategy that MS-DOS uses to allocate memory when a process requests it. If AL contains 0, the strategy is returned in AX. If AL contains 1, BX must contain the strategy. The three possible strategies are:

Table 1.27
Allocation Strategy

Value	Name	Description
0	First fit	MS-DOS starts searching at the lowest available block and allocates the first block it finds (the allocated memory is the lowest available block). This is the default strategy.
Value	Name	Description
1	Best fit	MS-DOS searches each available block and allocates the smallest available block that satisfies the request.
2	Last fit	MS-DOS starts searching at the highest available block and allocates the first block it finds (the allocated memory is the highest available block).

You can use this function request to control how MS-DOS uses its memory resources.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	AL doesn't contain 0 or 1, or BX doesn't contain 0, 1, or 2.

Macro Definition:

```
alloc_strat macro  code,strategy
            mov    bx,strategy
```

```
            mov    al,code
            mov    ah,58H
            int    21H
            endm
```

Example:

The following program displays the memory-allocation strategy in effect, then forces subsequent memory allocations to the top of memory by setting the strategy to last fit (code 2).

```
get       equ       0
set       equ       1
stdout    equ       1
last_fit  equ       2
;
first     db       "First fit     ",0DH,0AH
best      db       "Best fit      ",0DH,0AH
last      db       "Last fit      ",0DH,0AH
;
begin:    alloc_strat get               ;THIS FUNCTION
          jc         alloc_error        ;routine not shown
          mov        cl,4               ;multiply code by 16
          shl        ax,cl              ;to calculate offset
          mov        dx,offset first    ;point to first msg
          add        dx,ax              ;add to base address
          mov        bx,stdout          ;handle for write
          mov        cs,16              ;write 16 bytes
          mov        ah,40h             ;write handle
          int        21H                ;system call
;         jc         write_error        ;routine not shown
          alloc_strat set,last_fit      ;THIS FUNCTION
;         jc         alloc_error        ;routine not shown
```

Get Extended Error (Function 59H)

Call:

AH = 59H
BX = 0

Return:

AX
   Extended-error code
BH
   Error class (see text)
BL
   Suggested action (see text)
CH
   Locus (see text)

CL, DX, SI, DI, DS, ES destroyed

Comments:

Function 59H retrieves an extended-error code for the preceding system call. Each release of MS-DOS extends the error codes to cover new capabilities. These new codes are mapped to a simpler set of error codes

based on MS-DOS Version 2.0, so that existing programs can continue to operate correctly. Note that this call destroys all registers except CS:IP and SS:SP.

A user-written Interrupt 24H (Critical-Error Handler Address) can use Function 59H to get detailed information about the error that caused the interrupt to be issued.

The input BX is a version indicator that specifies for what level of error handling the application was written. The current level is 0.

The extended-error code consists of four separate codes in AX, BH, BL, and CH that give as much detail as possible about the error and suggest how the issuing program should respond.

BH--Error Class

BH returns a code that describes the class of error that occurred:

Class	Description
1	Out of a resource, such as storage or channels
2	Not an error, but a temporary situation (such as a locked region in a file) that is expected to end
3	Authorization problem
4	Internal error in system software
5	Hardware failure

Class	Description
6	System software failure not the fault of the active process (could be caused by missing or incorrect configuration files, for example)
7	Application program error
8	File or item not found
9	File or item of invalid format or type, or that is otherwise invalid or unsuitable
10	Interlocked file or item
11	Wrong disk in drive, bad spot on disk, or other problem with storage medium
12	Other error

BL--Suggested Action

BL returns a code that suggests how the issuing program can respond to the error:

Action	Description
1	Retry, then prompt user
2	Retry after a Pause

3 If user entered data such as drive letter or filename, prompt for it again

4 Terminate with cleanup

5 Terminate immediately; system so unhealthy that program should exit as soon as possible without taking time to close files and update indexes

6 Error is informational

7 Prompt user to perform some action, such as changing disks, then retry operation

CH--Locus

CH returns a code that provides additional information to help locate the area involved in the failure. This code is particularly useful for hardware failures (BH=5).

Locus	Description
1	Unknown
2	Related to random-access block devices, such as a disk drive
3	Related to Network
4	Related to serial-access character devices, such as a printer
5	Related to random-access memory

Your programs should handle errors by noting the error return from the original system call and then issuing this system call to get the extended-error code. If the program does not recognize the extended-error code, it should respond to the original error code.

This system call is available during Interrupt 24H and may be used to return network-related errors.

Macro Definition:

```
get_error  macro
           mov    ah, 59H
           int    21H
           endm
```

Example:

Since this function request provides such detailed information, a general example is not practical. User programs can interpret the various codes to determine what sort of messages or prompts should be displayed, what action to take, and whether to terminate the program if recovery from the errors isn't possible.

Create Temporary File (Function 5AH)

Call:

AH = 5AH
CX
   Attribute

DS:DX
   Pointer to pathname, followed by a
   byte of 0, and then by 13 bytes of memory

Return:

Carry set:
AX
   2 = File not found
   3 = Path not found
   4 = Too many open files
   5 = Access denied
Carry not set:
AX
   Handle

Comments:

Function 5AH creates a file with a unique name. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies a pathname and 13 bytes of memory (to hold the filename). CX must contain the attribute to be assigned to the file, as described in Section 1.5.5, "File Attributes," earlier in this chapter.

MS-DOS creates a unique filename and appends it to the pathname pointed to by DS:DX, creates the file and opens it in compatibility mode, then returns the file handle in AX. A program that needs a temporary file should use this function request to avoid name conflicts.

When the creating process exits, MS-DOS does not automatically delete a file created with Function 5AH. When you no longer need the file you should delete it.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	File is invalid or doesn't exist
3	Directory pointed to by DS:DX is invalid or doesn't exist
4	Too many open files (no handle available)
5	Access denied

Macro Definition:

```
create_temp macro  pathname,attrib
            mov    cx,attrib
            mov    dx,offset pathname
            mov    ah,5AH
            int    21H
            endm
```

Example:

The following program creates a temporary file in the directory named \wp\docs, copies a file named textfile.asc that is in the current directory into the temporary file, and then closes both files.

```
stdout   equ      1
;
```

```
file     db       "TEXTFILE.ASC",0
path     db       "\WP\DOCS",0
temp     db        13 dup (0)
open_msg db       " opened.",0DH,0AH
crl_msg  db       " created.",0DH,0AH
rd_msg   db       " read into buffer.",0DH,0AH
wr_msg   db       "Buffer written to "
cl_msg   db       "Files closed.",0DH,0AH
crlf     db       0DH,0AH
handle1  dw        ?
handle2  dw        ?
buffer   db        512 dup (?)
;
begin:   open_handle file,0               ;see Function 3DH
         jc         open_error            ;routine not shown
         mov        handle1,ax            ;save handle
         write_handle stdout,file,12      ;see Function 40H
         jc         write_error           ;routine not shown
         write_handle stdout,open_msg,10  ;see Function 40H
         jc         write_error           ;routine not shown
         create_temp path,0               ;THIS FUNCTION
         jc         create_error          ;routine not shown
         mov        handle2,ax            ;save handle
         write_handle stdout,path,8       ;see Function 40H
         jc         write_error           ;routine not shown
         display_char "
         write_handle stdout,temp,12      ;see Function 40H
         jc         write_error           ;routine not shown
         write_handle stdout,crl_msg,11   ;See Function 40H
         jc         write_error           ;routine not shown
         read_handle handle1,buffer,512   ;see Function 3FH
         jc        read_error             ;routine not shown
         write_handle stdout,file,12      ;see Function 40H
         jc        write_error            ;routine not shown
         write_handle stdout,rd_msg,20    ;see Function 40H
         jc        write_error            ;routine not shown
         write_handle handle2,buffer,512  ;see Function 40H
         jc        write_error            ;routine not shown
         write_handle stdout,wr_msg,18    ;see Function 40H
         jc         write_error           ;routine not shown
         write_handle stdout,temp,12      ;see Function 40H
         jc         write_error           ;routine not shown
         write_handle stdout,crlf,2       ;see Function 40H
         jc        write_error            ;routine not shown
         close_handle handle1             ;see Function 3EH
         jc        close_error            ;routine not shown
         close_handle handle2             ;see Function 3EH
         jc        close_error            ;routine not shown
         write_handle stdout,cl_msg,15    ;see Function 40H
         jc        write_error            ;routine not shown
```

Create New File (Function 5BH)

Call:

AH = 5BH
CX
   Attribute
DS:DX
   Pointer to pathname

Return:

```
Carry set:
AX
    2     = File not found
    3     = Path not found
    4     = Too many open files
    5     = Access denied
   80     = File already exists
Carry not set:
AX
   Handle
```

Comments:

Function 5BH creates a new file. DX must contain the offset (from the segment address in DS) of an ASCIZ string that specifies a pathname. CX contains the attribute to be assigned to the file, as described in Section 1.5.5, "File Attributes."

If there is no existing file with the same filename, MS-DOS creates the file, opens it in compatibility mode, and returns the file handle in AX.

This function request fails if the specified file exists, unlike Function 3CH (Create Handle), which, under the same circumstances, truncates the file to a length of 0. In a multitasking system, the existence of a file is used as a semaphore; you can use this system call as a test-and-set semaphore.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
2	File is invalid or doesn't exist
3	Directory pointed to by DS:DX is invalid or doesn't exist
4	No free handles are available in the current process, or internal system tables are full
5	Access denied
80	File with the same specification pointed to by DS:DX already exists

Macro Definition:

```
create_new macro  pathname,attrib
           mov    cx, attrib
           mov    dx, offset pathname
           mov    ah, 5BH
           int    21H
           endm
```

Example:

The following program attempts to create a new file named report.asm in the current directory. If the file already exists, the program displays an error message and returns to MS-DOS. If the file doesn't exist and there

are no other errors, the program saves the handle and continues processing.

```
err_msg  db       "FILE ALREADY EXISTS",0DH,0AH,"$"
path     db       "report.asm",0
handle   dw        ?
;
begin:    create_new path,0             ;THIS FUNCTION
          jnc        continue           ;further processing
          cmp        ax,80              ;file already exist?
          jne        error              ;routine not shown
          display    err_msg            ;see Function 09H
          jmp        return             ;return to MS-DOS
continue: mov        handle,ax          ;save handle
;
;         (further processing here)
```

Lock (Function 5CH, Code 00H)

Call:

```
AH = 5CH
AL = 00H
BX
   Handle
CX:DX
   Offset of region to be locked
SI:DI
   Length of region to be locked
```

Return:

```
Carry set:
AX
   1      = Invalid function code
   6      = Invalid handle
  33      = Lock violation
  36      = Sharing buffer exceeded
Carry not set:
   No error
```

Comments:

Function 5CH, Code 00H, denies all access (read or write) by any other process to the specified region of the file. BX must contain the handle of the file that contains the region to be locked. CX:DX (a four-byte integer) must contain the offset in the file of the beginning of the region. SI:DI (a four-byte integer) must contain the length of the region.

If another process attempts to use (read or write) a locked region, MS-DOS retries three times; if the retries fail, MS-DOS issues Interrupt 24H for the requesting process. You can change the number of retries with Function 44H, Code 0BH (IOCtl Retry).

The locked region can be anywhere in the file. For instance, locking beyond the end of the file is not an error. A region should be locked for only a brief period, so if it is locked for more than ten seconds you should consider it to be an error.

Function 45H (Duplicate File Handle) and Function 46H (Force Duplicate File Handle) duplicate access to any locked region. Passing an open file to

a child process with Function 4BH, Code 00H (Load and Execute Program) does not duplicate access to locked regions.

.....
Warning
  If a program closes a file that contains a locked region or terminates
  with an open file that contains a locked region, the result is undefined.
.....

Programs that might be terminated by Interrupt 23H (CONTROL-C Handler Address) or Interrupt 24H (Critical-Error-Handler Address) should trap these interrupts and unlock any locked regions before exiting.

Programs should not rely on being denied access to a locked region. A program can determine the status of a region (locked or unlocked) by attempting to lock the region and examining the error code.

If there is an error, the carry flag (CF) is set and the error code is returned in AX:

Code	Meaning
1	File sharing must be loaded to use this function request.
6	The handle in BX is not a valid, open handle.
33	All or part of the specified region is already locked.
36	There is no more room for lock entries in the buffer. Refer to the share command in the MS-DOS User's Reference for information on allocating more lock entries.

Macro Definition:

```
lock  macro  handle,start,bytes
      mov    bx, handle
      mov    cx, word ptr start
      mov    dx, word ptr start+2
      mov    si, word ptr bytes
      mov    di, word ptr bytes+2
      mov    al, 0
      mov    ah, 5CH
      int    21H
      endm
```

Example:

The following program opens a file named finalrpt in "Deny None" mode and locks two portions of it: the first 128 bytes and bytes 1024 through 5119. After some (unspecified) processing, it unlocks the same portions and closes the file.

```
stdout    equ        1
;
start1    dd         0
lgth1     dd         128
start2    dd         1023
lgth2     dd         4096
file      db        "FINALRPT",0
op_msg    db        " opened.",0DH,0AH
11_msg    db        "First 128 bytes locked.",0DH,0AH
12_msg    db        "Bytes 1024-5119 locked.",0DH,0AH
```

```
u1_msg    db        "First 128 bytes unlocked.",0DH,0AH
u2_msg    db        "Bytes 1024-5119 unlocked.",0DH,0AH
cl_msg    db        " closed.:,0DH,0AH
handle    dw         ?
;
begin:    open_handle file,01000010b     ;see Function 3DH
          jc         open_error          ;routine not shown
          write_handle stdout,file,8     ;see Function 40H
          jc         write_error         ;routine not shown
          write_handle stdout,op_msg,10  ;see Function 40H
          jc         write_error         ;routine not shown
          mov        handle,ax           ;save handle
          lock       handle,start1,lgth1 ;THIS FUNCTION
          jc         lock_error          ;routine not shown
          write_handle stdout,11_msg,25  ;see Function 40H
          jc         write_error         ;routine not shown
          lock       handle,start2,lgth2 ;THIS FUNCTION
          jc         lock_error          ;routine not shown
          write_handle stdout,12_msg,25  ;see Function 40H
          jc         write_error         ;routine not shown
;
; ( Further processing here )
;
          unlock     handle,start1,lgth1 ;See Function 5C01H
          jc         unlock_error        ;routine not shown
          write_handle stdout,ul_msg,27  ;see Function 40H
          jc         write_error         ;routine not shown
          unlock     handle,start2,lgth2 ;See Function 5C01H
          jc         unlock_error        ;routine not shown
          write_handle stdout,u2_msg,27  ;See Function 40H
          jc         write_error         ;routine not shown
          close_handle handle            ;See Function 3EH
          jc         close_error         ;routine not shown
          write_handle stdout,file,8     ;see Function 40H
          jc         write_error         ;routine not shown
          write_handle stdout,cl_msg,10  ;see Function 40H
          jc         write_error         ;routine not shown
```

Unlock (Function 5CH, Code 01H)

Call:

AH = 5CH
AL = 01H
BX
   Handle
CX:DX
   Offset of area to be unlocked
SI:DI
   Length of area to be unlocked

Return:

Carry set:
AX
   1   = Invalid function code
   6   = Invalid handle
  33   = Lock violation
  36   = Sharing buffer exceeded
Carry not set:
   No error

Comments:

Function 5CH, Code 01H, unlocks a region previously locked by the same process. BX must contain the handle of the file that contains the region to be unlocked. CX:DX (a four-byte integer) must contain the offset in the file of the beginning of the region. SI:DI (a four-byte integer) must contain the length of the region. The offset and length must be exactly the same as the offset and length specified in the previous Function 5CH, Code 00H (Lock).

The description of Function 5CH, Code 00H (Lock) describes how to use locked regions.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	File sharing must be loaded to use this function request.
6	The handle in BX is not a valid, open handle.
33	The region specified is not identical to one that was previously locked by the same process.
36	There is no more room for lock entries in the buffer. Refer to the share command in the MS-DOS User's Reference for information on allocating more lock entries.

You should issue Function 59H (Get Extended Error) to list the possible errors returned by this function.

Macro Definition:

```
unlock  macro  handle,start,bytes
        mov    bx, handle
        mov    cx, word ptr start
        mov    dx, word ptr start+2
        mov    si, word ptr bytes
        mov    di, word ptr bytes+2
        mov    al, 1
        mov    ah, 5CH
        int    21H
        endm
```

Example:

The following program opens a file named finalrpt in "Deny None" mode and locks two portions of it: the first 128 bytes and bytes 1024 through 5119. After some (unspecified) processing, it unlocks the same portions and closes the file.

```
stdout    equ        1
;
start1    dd         0
lgth1     dd         128
start2    dd         1023
lgth2     dd         4096
file      db        "FINALRPT",0
op_msg    db        " opened.",0DH,0AH
```

```
11_msg    db        "First 128 bytes locked.",0DH,0AH
12_msg    db        "Bytes 1024-5119 locked.",0DH,0AH
u1_msg    db        "First 128 bytes unlocked.",0DH,0AH
u2_msg    db        "Bytes 1024-5119 unlocked.",0DH,0AH
cl_msg    db        " closed.",0DH,0AH
handle    dw         ?
;
begin:    open_handle file,01000010b     ;see Function 3DH
          jc         open_error          ;routine not shown
          write_handle stdout,file,8     ;see Function 40H
          jc         write_error         ;routine not shown
          write_handle stdout,op_msg,10  ;see Function 40H
          jc         write_error         ;routine not shown
          mov        handle,ax           ;save handle
          lock       handle,start1,lgth1 ;See Function 5C00H
          jc         lock_error          ;routine not shown
          write_handle stdout,11_msg,25  ;see Function 40H
          jc         write_error         ;routine not shown
          lock       handle,start2,lgth2 ;See Function 5C00H
          jc         lock_error          ;routine not shown
          write_handle stdout,12_msg,25  ;see Function 40H
          jc         write_error         ;routine not shown
;
; ( Further processing here )
;
          unlock     handle,start1,lgth1 ;THIS FUNCTION
          jc         unlock_error        ;routine not shown
          write_handle stdout,u1_msg,27  ;see Function 40H
          jc         write_error         ;routine not shown
          unlock     handle,start2,lgth2 ;THIS FUNCTION
          jc         unlock_error        ;routine not shown
          write_handle stdout,u2_msg,27  ;see Function 40H
          jc         write_error         ;routine not shown
          close_handle handle            ;See Function 3EH
          jc         close_error         ;routine not shown
          write_handle stdout,file,8     ;see Function 40H
          jc         write_error         ;routine not shown
          write_handle stdout,cl_msg,10  ;see Function 40H
          jc         write_error         ;routine not shown
```

Get Machine Name (Function 5EH, Code 00H)

Call:

AH = 5EH
AL = 0
DS:DX
   Pointer to 16-byte buffer

Return:

Carry set:
AX
   1 = Invalid function code
Carry not set:
CX
   Identification number of local
   computer

Comments:

Function 5EH, Code 0, retrieves the net name of the local computer. DX must contain the offset (to the segment address in DS) of a 16-byte buffer. Microsoft Networks must be running.

MS-DOS returns the local computer name (a 16-byte ASCIZ string, padded with blanks) in the buffer pointed to by DS:DX. CX returns the identification number of the local computer. If the network was never installed, the CH register returns with zero and the value in the CL register is invalid.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	Microsoft Networks must be running to use this function request.

Macro Definition:

```
get_machine_name  macro  buffer
                  mov    dx,offset buffer
                  mov    al,0
                  mov    ah,5EH
                  int    21H
                  endm
```

Example:

The following program displays the name of a Microsoft Networks work-station.

```
stdout equ 1
;
msg        db   "Netname: "
mac_name   db   16 dup (?),0DH,0AH
;
begin:    get_machine_name  mac_name        ;THIS FUNCTION
          jc                name_error      ;routine not shown
          write_handle      stdout,msg,27   ;see Function 40H
          jc                write_error     ;routine not shown
```

Printer Setup (Function 5EH, Code 02H)

Call:

AH = 5EH
AL = 02H
BX
   Assign-list index
CX
   Length of setup string
DS:SI
   Pointer to setup string

Return:

Carry set:
AX

   1 = Invalid function code
Carry not set:
   No error

Comments:

Function 5EH, Code 02H, defines a string of control characters that MS-DOS adds to the beginning of each file sent to the network printer. BX must contain the index into the assign list that identifies the printer (entry 0 is the first entry). CX must contain the length of the string. SI must contain the offset (to the segment address in DS) of the string itself. Microsoft Networks must be running.

MS-DOS adds the setup string to the beginning of each file sent to the printer, which is specified by the assign-list index in BX. This function request lets each program that shares a printer have its own printer configuration. You can use Function 5F02H (Get Assign-List Entry) to determine which entry in the assign list refers to the printer.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	Microsoft Networks must be running to use this function request.

Macro Definition:

```
printer_setup  macro  index,lgth,string
               mov    bx, index
               mov    cx, lgth
               mov    dx, offset string
               mov    al, 2
               mov    ah, 5EH
               int    21H
               endm
```

Example:

The following program defines a printer-setup string that consists of the control character to print expanded type on Epson-compatible printers. The printer cancels this mode at the first carriage return, so the effect is to print the first line of each file sent to the network printer as a title in expanded characters. The setup string is one character. This example assumes that the printer is the entry number 3 (the fourth entry) in the assign list. Use Function 5F02H (Get Assign-List Entry) to determine this value.

```
setup     db   0EH
;
begin:    printer_setup 3,1,setup       ;THIS FUNCTION
          jc            error           ;routine not shown
```

Get Assign-List Entry (Function 5FH, Code 02H)

Call:

AH = 5FH
AL = 02H

BX
   Assign-list index
DS:SI
   Pointer to buffer for local name
ES:DI
   Pointer to buffer for remote name

Return:

Carry set:
AX
   1 = Invalid function code
  18 = No more files
Carry not set:
BL
   3 = Printer
   4 = Drive
CX
   Stored user value

Comments:

Function 5FH, Code 02H, retrieves the specified entry from the network list of assignments. BX must contain the assign-list index (entry 0 is the first entry). SI must contain the offset (to the segment address in DS) of a 16-byte buffer for the local name. DI must contain the offset (to the segment address in ES) of a 128-byte buffer for the remote name. Microsoft Networks must be running.

MS-DOS puts the local name in the buffer pointed to by DS:SI and the remote name in the buffer pointed to by ES:DI. The local name can be a null ASCIZ string. BL returns 3 if the local device is a printer or 4 if the local device is a drive. CX returns the stored user value set with Function 5F03H (Make Assign-List Entry). The contents of the assign list can change between calls.

You can use this function request to retrieve any entry, or to make a copy of the complete list by stepping through the table. To detect the end of the assign list, check for error code 18 (no more files), as you would when stepping through a directory by using Functions 4EH (Find First File) and 4FH (Find Next File).

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	Microsoft Networks must be running to use this function request.
18	The index passed in BX is greater than the number of entries in the assign list.

Macro Definition:

```
get_list  macro  index,local,remote
          mov    bx, index
          mov    si, offset local
          mov    di, offset remote
          mov    al,2
          mov    ah, 5FH
          int    21H
```

```
          endm
```

Example:

The following program displays the assign list on a Microsoft Networks workstation, showing the local name, remote name, and device type (drive or printer) for each entry.

```
stdout    equ        1
printer   equ        3
;
local_nm  db         16 dup (?),2 dup (20h)
remote_nm db         128 dup (?),2 dup (20h)
header    db        "Local name",8 dup (20h)
          db        "Remote name",7 dup (20h)
          db        "Device Type"
crlf      db         0dh,0ah,0dh,0ah
drive_msg db        "drive"
print_msg db        "printer"
index     dw         ?
;
begin:    write_handle stdout,header,51       ;see Function 40H
          jc         write_error              ;routine not shown
          mov        index,0                  ;assign list index
ck_list:  get_list   index,local_nm,remote_nm ;THIS FUNCTION
          jnc        got_one                  ;got an entry
error:    cmp        ax,18
          je         last_one                 ;yes
          jmp        error                    ;routine not shown
got_one:  push       bx                       ;save device type
          write_handle  stdout,local_nm,148   ;see Function 40H
          jc         write_error              ;routine not shown
          pop        bx                       ;get device type
          cmp        bl,printer               ;is it a printer?
          je         prntr                    ;yes
          write_handle stdout,drive_msg,5     ;see Function 40H
          jc         write_error              ;routine not shown
          jmp        get_next                 ;finish message
prntr:    write_handle stdout,print_msg,7     ;see Function 40H
          jc         write_error              ;routine not shown
get_next: write_handle stdout,crlf,2          ;see Function 40H
          jc         write_error              ;routine not shown
          inc        index                    ;bump index
          jmp        ck_list                  ;get next entry
last_one: write_handle stdout,crlf,4          ;see Function 40H
          jc         write_error              ;routine not shown
;
```

Make Assign-List Entry (Function 5FH, Code 03H)

Call:

AH = 5FH
AL = 03H
BL
   3 = Printer
   4 = Drive
CX
   User value
DS:SI
   Pointer to name of source device

ES:DI
   Pointer to name of destination
   device

Return:

Carry set:
AX
   1 = Invalid function code
   5 = Access denied
   3 = Path not found
   8 = Insufficient memory
   (Other errors particular to the
   network may occur.)
Carry not set:
   No error

Comments:

Function 5FH, Code 03H, redirects a printer or disk drive (source device) to a network directory (destination device). BL must contain 3 if the source device is a printer or 4 if it is a disk drive. SI must contain the offset (to the segment address in DS) of an ASCIZ string that specifies the name of the printer, or a drive letter followed by a colon, or a null string (one byte of 00H). DI must contain the offset (to the segment address in ES) of an ASCIZ string that specifies the name of a network directory. CX contains a user-specified 16-bit value that MS-DOS maintains. Microsoft Networks must be running.

The destination string must be an ASCIZ string of the following form:

machine-name pathname 00H password 00H

where:

Machine-name is the net name of the server that contains the network directory;

Pathname is the alias of the network directory (not the directory path) to which the source device is to be redirected;

00H is a null byte; and

Password is the password for access to the network directory. If no password is specified, both null bytes must immediately follow the pathname.

If BL=3, the source string must be PRN, LPT1, LPT2, or LPT3. This function buffers and sends all output for the named printer to the remote-printer spooler named in the destination string.

If BL=4, the source string can be either a drive letter followed by a colon, or a null string. If the source string contains a valid drive letter and colon, this call redirects all subsequent drive-letter references to the network directory named in the destination string. If the source string is a null string, MS-DOS attempts to grant access to the network directory with the specified password.

The maximum length of the destination string is 128 bytes. You can retrieve the value in CX by using Function 5FH, Code 02H (Get Assign-List Entry).

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	Microsoft Networks must be running to use this function request; the value in BX is not 1 to 4, the source string is in the wrong format; the destination string is in the wrong format; or the source device is already redirected.
3	The network directory path is invalid or doesn't exist.
5	The network directory/password combination is not valid. This does not mean that the password itself was invalid; the directory might not exist on the server.
8	There is not enough memory for string substitutions.

Macro Definition:

```
redir macro  device,value,source,destination
      mov    bl, device
      mov    cx, value
      mov    si, offset source
      mov    es, seg destination
      mov    di, offset destination
      mov    al, 03H
      mov    ah, 5FH
      int    21H
      endm
```

Example:

The following program redirects two drives and a printer from a workstation to a server named harold. It assumes the machine name, directory names, and driver letters shown:

Local drive or printer	Netname on server	Password
E:	WORD	none
F:	COMM	fred
PRN:	PRINTER	quick

```
printer   equ  3
drive     equ  4
;
local_1   db  "e:",0
local_2   db  "f:",0
local_3   db  "prn",0
remote_1  db  "\harold\word",0,0
remote_2  db  "\harold\comm",0,"fred",0
remote_3  db  "\harold\printer",0,"quick",0
;
begin:    redir  local_1,remote_1,drive,0     ;THIS FUNCTION
          jc     error                        ;routine not shown
          redir  local_2,remote_2,drive,0     ;THIS FUNCTION
          jc     error                        ;routine not shown
          redir  local_3,remote_3,printer,0   ;THIS FUNCTION
          jc     error                        ;routine not shown
```

Cancel Assign-List Entry (Function 5FH, Code 04H)

Call:

AH = 5FH
AL = 04H
DS:SI
   Pointer to name of source device

Return:

Carry set:
AX
   1   = Invalid function code
  15   = Redirection paused on server
  (Other errors particular to the network
  may occur.)
Carry not set:
   No error

Comments:

Function 5FH, Code 04H, cancels the redirection of a printer or disk drive (source device) to a network directory (destination device) made with Function 5FH, Code 03H (Make Assign-List Entry). SI must contain the offset (to the segment address in DS) of an ASCIZ string that specifies the name of the printer or drive whose redirection is to be canceled. Microsoft Networks must be running.

The ASCIZ string pointed to by DS:SI can contain one of three values:

- The letter of a redirected drive, followed by a colon. Cancels the redirection and restores the drive to its physical meaning.

- The name of a redirected printer (PRN, LPT1, LPT2, LPT3, or their machine-specific equivalents). Cancels the redirection and restores the printer name to its physical meaning.

- A string starting with \\ (2 backslashes). Terminates the connection between the local machine and the network directory.

If there is an error, the carry flag (CF) is set and the error code returns in AX:

Code	Meaning
1	Microsoft Networks must be running to use this function request; or the ASCIZ string names a nonexistent source device.
15	Disk or printer redirection on the network server is paused.

Macro Definition:

```
cancel_redir  macro  local
              mov    si, offset local
              mov    al, 4
              mov    ah, 5FH
              int    21H
              endm
```

Example:

The following program cancels the redirection of drives E and F and the printer (PRN) of a Microsoft Networks workstation. It assumes that these local devices were redirected previously.

```
local_1   db        "e:",0
local_2   db        "f:",0
local_3   db        "prn",0
;
begin:    cancel_redir  local_1    ;THIS FUNCTION
          jc            error      ;routine not shown
          cancel_redir  local_2    ;THIS FUNCTION
          jc            error      ;routine not shown
          cancel_redir  local_3    ;THIS FUNCTION
          jc            error      ;routine not shown
```

Get PSP (Function 62H)

Call:

AH = 62H

Return:

BX
   Segment address of the Program
   Segment Prefix of the current process

Comments:

Function 62H retrieves the segment address of the currently active process (the start of the Program Segment Prefix). The address returns in BX.

Macro Definition:

```
get_psp macro
        mov    ah, 62H
        int    21H
        endm
```

Example:

The following program displays the segment address of its Program Segment Prefix (PSP) in hexadecimal.

```
msg       db       "PSP segment address:  H",0DH,0AH,"$"
;
begin:    get_psp                       ;THIS FUNCTION
          convert   bx,16,msg[21]       ;see end of chapter
          display   msg                 ;see Function 09H
```

Get Extended Country Information (Function 65H)

Call:

AH = 65H
AL
  Function (minor) code
BX
  Code page (-1 = active CON device)
CX
  Amount of data to return
DX
  Country ID for which information is to be returned
  (-1=default country)
ES:DI
  Address of country information buffer

Return:

1 = Buffer has been filled
2 = File not found

Comments:

Function 65H retrieves standard country information. This information includes country ID, code page, date and time format, currency symbol, separators (for thousands, decimals, data list, date and time) currency format flags, digits in currency, and case-mapping information.

The function code passed in AL may be one of the following:

Code	Description
1	Return standard information
2	Return pointer to uppercase table
3	Return pointer to filename uppercase table
4	Return pointer to collating table
5	Reserved (no entry)
6	Return pointer to collating sequence

MS-DOS 3.3 provides more country-dependent information than previous versions of MS-DOS. Only the information for the default country is kept in the kernel. Country-dependent information for all other countries is contained in the country.sys file. The MS-DOS nlsfunc command is used to access the country-dependent information in country.sys using this call. If the country code and code page number do not match, or if either is invalid, error code 2 is returned to AX. If CX is less than 5, error code 1 is returned. If the amount of information requested is greater than the value of CX, only CX bytes are returned and no error is reported.

If AL = 1, the buffer is filled with the following information:

```
db    1    ;  Information ID
dw    ?    ;  Size (<=38)
dw    ?    ;  Country ID
dw    ?    ;  Code page
```

If AL = 2, the buffer is filled with the following information:

```
db    2    ;  Information ID
dd    ?    ;  Double-word pointer to uppercase table
```

If AL = 4, the buffer is filled with the following information:

```
db    4    ;  Information ID
dd    ?    ;  Double-word pointer to filename uppercase table
```

Both of these tables consist of a length field (two bytes) followed by 128 uppercase values for the upper 128 ASCII characters. The following formula is used to compute the address of an uppercase equivalent in the table:

Address of outchar = inchar - (256-table_len) = table_start

where:

Parameter	Meaning
inchar	Character to be generated
table_len	Length of list of uppercase values (two bytes)
table_start	Starting address of uppercase table
outchar	Uppercase value for inchar

If inchar is greater than or equal to (256 - table_len), there is an uppercase equivalent in the table; otherwise, there is not.

If AL = 6, the buffer is filled with the following information:

```
db    6    ;  Information ID
dd    ?    ;  Double-word pointer to collating sequence
```

The table is 258 bytes long. The first word is the length of the table. The rest of the table is 256 ASCII values in the appropriate order.

Get/Set Global Code Page (Function 66H)

Call:

AH = 66H
AL
  Function (minor) code
BX
  Code page to set (AL = 2)

Return:

Carry set:
AX
 02 = File not found
 65 = Device not selected
Carry not set:
  No error

Comments:

Function 66H gets or sets the code page used by the kernel and all devices. If no other code page has been set, this function gets the default code page from DX. If another code page is set, this function retrieves the active code page from BX.

The MS-DOS nlsfunc command and country.sys must be on the system if this function is to be used to change the global code page.

The function code may be one of the following:

Code	Description
1	Get code page

2 Set code page

MS-DOS gets the new code page from the country.sys file. Devices must be prepared for code page switching before a code page can be selected. To prepare a device, a device driver that supports code page switching must be installed by using the device command in the config.sys file. The user must also use the prepare keyword with the MS-DOS mode command to prepare the device for code page switching.

The code page selected must be compatible with the country code specified in the config.sys file. If MS-DOS cannot read country.sys or other specified country information file, error code 02 is returned to AX.

Set Handle Count (Function 67H)

Call:

AH = 67H
BX
  Number of allowed handles

Return:

Carry set:
AX
Carry not set:
  No error

Comments:

Function 67H increases or decreases the number of files a program can have open at one time. The maximum number of files handles is 64K. If less than 20 are specified, the minimum handle number, 20, is assumed. If this call is used to reduce the number of allowed handles, the new limit does not take affect until any handles above the new limit are closed.

The user should use Call 4AH (Set Block) to allocate memory for the extended handle list if BX is greater than 255. The maximum number for the value of the config.sys command files is 255.

Commit File (Function 68H)

Call:

AH = 68H
BX
  File handle

Return:

Carry set:
AX = error
Carry not set
  No error

Comments:

Function 68H flushes all buffered data for a file without closing it. Using this call is more efficient than using the traditional close-open sequence, and is more effective for network environments. This call makes sure that the disk image of a file is current.

```
; Macro Definitions for MS-DOS System Call Examples
;
;*******************
; Interrupts
;*******************
;                                Interrupt 25H
ABS_DISK_READ  macro  disk,buffer,num_sectors,first_sector
     mov    al,disk
     mov    bx,offset buffer
     mov    cx,num_sectors
     mov    dx,first_sector
     int    25H
     popf
     endm

;                                Interrupt 26H
ABS_DISK_WRITE  macro  disk,buffer,num_sectors,first_sector
     mov    al,disk
     mov    bx,offset buffer
     mov    cx,num_sectors
     mov    dx,first_sector
     int    26H
     popf
     endm

;                                Interrupt 27H
STAY_RESIDENT  macro  last_instruc
     mov    dx,offset last_instruc
     inc    dx
     int    27H
     endm
;
;
;*******************
; Function Requests
;*******************
;                                Function Request 00H
TERMINATE_PROGRAM  macro
     xor    ah,ah
     int    21H
     endm

;                                Function Request 01H
READ_KBD_AND_ECHO  macro
     mov    ah,01H
     int    21H
     endm
;                                Function Request 02H
DISPLAY_CHAR  macro  character
     mov    dl,character
     mov    ah,02H
     int    21H
     endm

;                                Function Request 03H
AUX_INPUT    macro
     mov     ah,03H
     int     21H
```

```
     endm

;                                    Function Request 04H
AUX_OUTPUT  macro
     mov    ah,04H
     int    21H
     endm
;                                    Function Request 05H
PRINT_CHAR  macro  character
     mov    dl,character
     mov    ah,05H
     int    21H
     endm

;                                    Function Request 06H
DIR_CONSOLE_IO  macro  switch
     mov    dl,switch
     mov    ah,06H
     int    21H
     endm
;                                    Function Request 07H
DIR_CONSOLE_INPUT  macro
     mov    ah,07H
     int    21H
     endm

;                                    Function Request 08H
READ_KBD  macro
     mov    ah,08H
     int    21H
     endm
;                                    Function Request 09H
DISPLAY  macro  string
     mov    dx,offset string
     mov    ah,09H
     int    21H
     endm

;                                    Function Request 0AH
GET_STRING  macro  limit,string
     mov    dx,offset string
     mov    string,limit
     mov    ah,0AH
     int    21H
     endm
;                                    Function Request 0BH
CHECK_KBD_STATUS  macro
     mov    ah,0BH
     int    21H
     endm

;                                    Function Request 0CH
FLUSH_AND_READ_KBD  macro  switch
     mov    al,switch
     mov    ah,0CH
     int    21H
     endm

;                                    Function Request 0DH
RESET_DISK  macro
     mov    ah,0DH
     int    21H
     endm
;                                    Function Request 0EH
```

```
SELECT_DISK  macro  disk
     mov    dl,disk[-65]
     mov    ah,0EH
     int    21H
     endm

;                                    Function Request 0FH
OPEN  macro  fcb
     mov    dx,offset fcb
     mov    ah,0FH
     int    21H
     endm
;                                    Function Request 10H
CLOSE  macro  fcb
     mov    dx,offset fcb
     mov    ah,10H
     int    21H
     endm

;                                    Function Request 11H
SEARCH_FIRST  macro  fcb
     mov    dx,offset fcb
     mov    ah,11H
     int    21H
     endm
;                                    Function Request 12H
SEARCH_NEXT  macro  fcb
     mov    dx,offset fcb
     mov    ah,12H
     int    21H
     endm

;                                    Function Request 13H
DELETE  macro  fcb
     mov    dx,offset fcb
     mov    ah,13H
     int    21H
     endm

;                                    Function Request 14H
READ_SEQ  macro  fcb
     mov    dx,offset fcb
     mov    ah,14H
     int    21H
     endm
;                                    Function Request 15H
WRITE_SEQ  macro  fcb
     mov    dx,offset fcb
     mov    ah,15H
     int    21H
     endm

;                                    Function Request 16H
CREATE  macro  fcb
     mov    dx,offset fcb
     mov    ah,16H
     int    21H
     endm
;                                    Function Request 17H
RENAME  macro  fcb,newname
     mov    dx,offset fcb
     mov    ah,17H
     int    21H
     endm
```

```
;                                   Function Request 19H
CURRENT_DISK  macro
     mov    ah,19H
     int    21H
     endm
;                                   Function Request 1AH
SET_DTA  macro  buffer
     mov    dx,offset buffer
     mov    ah,1AH
     endm

;                                   Function Request 1BH
DEF_DRIVE_DATA  macro
     mov    ah,1BH
     int    21H
     endm
;                                   Function Request 1CH
DRIVE_DATA  macro  drive
     mov    dl,drive
     mov    ah,1CH
     int    21H
     endm

;                                   Function Request 21H
READ_RAN  macro  fcb
     mov    dx,offset fcb
     mov    ah,21H
     int    21H
     endm

;                                   Function Request 22H
WRITE_RAN  macro  fcb
     mov    dx,offset fcb
     mov    ah,22H
     int    21H
     endm
;                                   Function Request 23H
FILE_SIZE  macro  fcb
     mov    dx,offset fcb
     mov    ah,23H
     int    21H
     endm

;                                   Function Request 24H
SET_RELATIVE_RECORD  macro  fcb
     mov    dx,offset fcb
     mov    ah,24H
     int    21H
     endm
;                                   Function Request 25H
SET_VECTOR  macro  interrupt,handler_start
     mov    al,interrupt
     mov    dx,offset handler_start
     mov    ah,25H
     int    21H
     endm

;                                   Function Request 26H
CREATE_PSP  macro  seg_addr
     mov    dx,offset seg_addr
     mov    ah,26H
     int    21H
     endm
```

```
;                                   Function Request 27H
RAN_BLOCK_READ  macro  fcb,count,rec_size
     mov    dx,offset fcb
     mov    cx,count
     mov    word ptr fcb[14],rec_size
     mov    ah,27H
     int    21H
     endm

;                                   Function Request 28H
RAN_BLOCK_WRITE  macro  fcb,count,rec_size
     mov    dx,offset fcb
     mov    cx,count
     mov    word ptr fcb[14],rec_size
     mov    ah,28H
     int    21H
     endm

;                                  Function Request 29H
PARSE  macro  string,fcb
     mov    si,offset string
     mov    di,offset fcb
     push   es
     push   ds
     pop    es
     mov    al,0FH
     mov    ah,29H
     int    21H
     pop    es
     endm

;                                   Function Request 2AH
GET_DATE  macro
     mov    ah,2AH
     int    21H
     endm

;                                   Function Request 2BH
SET_DATE  macro  year,month,day
     mov    cx,year
     mov    dh,month
     mov    dl,day
     mov    ah,2BH
     int    21H
     endm

;                                   Function Request 2CH
GET_TIME  macro
     mov    ah,2CH
     int    21H
     endm

;                                   Function Request 2DH
SET_TIME  macro  hour,minutes,seconds,hundredths
     mov    ch,hour
     mov    cl,minutes
     mov    dh,seconds
     mov    dl,hundredths
     mov    ah,2DH
     int    21H
     endm

;                                   Function Request 2EH
VERIFY  macro  switch
```

```
     mov    al,switch
     mov    ah,2EH
     int    21H
     endm

;                                    Function Request 2FH
GET_DTA  macro
     mov    ah,2FH
     int    21H
     endm

;                                    Function Request 30H
GET_VERSION  macro
     mov    ah,30H
     int    21H
     endm

;                                    Function Request 31H
KEEP_PROCESS  macro  return_code,last_byte
     mov    al,return_code
     mov    dx,offset last_byte
     mov    cl,4
     shr    dx,cl
     inc    dx
     mov    ah,31H
     int    21H
     endm

;                                    Function Request 33H
CTRL_C_CK  macro  action,state
     mov    al,action
     mov    dl,state
     mov    ah,33H
     int    21H
     endm

;                                    Function Request 35H
GET_VECTOR  macro  interrupt
     mov    al,interrupt
     mov    ah,35H
     int    21H
     endm

;                                    Function Request 36H
GET_DISK_SPACE  macro  drive
     mov    dl,drive
     mov    ah,36H
     int    21H
     endm

;                                    Function Request 38H
GET_COUNTRY  macro  country,buffer
             local  gc_01
             mov    dx,offset buffer
             mov    ax,country
             cmp    ax,0FFH
             jl     gc_01
             mov    al,0ffh
             mov    bx,country
gc_01:       mov    ah,38H
             int    21H
             endm

;                                    Function Request 38H
```

```
SET_COUNTRY  macro  country
             local  sc_01
             mov    dx,0FFFFH
             mov    ax,country
             cmp    ax,0FFH
             jl     sc_01
             mov    al,0ffh
             mov    bx,country
sc_01:       mov    ah,38H
             int    21H
             endm

;                                  Function Request 39H
MAKE_DIR  macro  path
     mov    dx,offset path
     mov    ah,39H
     int    21H
     endm

;                                  Function Request 3AH
REM_DIR  macro  path
     mov    dx,offset path
     mov    ah,3AH
     int    21H
     endm

;                                  Function Request 3BH
CHANGE_DIR  macro  path
     mov    dx,offset path
     mov    ah,3BH
     int    21H
     endm

;                                  Function Request 3CH
CREATE_HANDLE  macro  path,attrib
     mov    dx,offset path
     mov    cx,attrib
     mov    ah,3CH
     int    21H
     endm

;                                  Function Request 3DH
OPEN_HANDLE  macro  path,access
     mov    dx,offset path
     mov    al,access
     mov    ah,3DH
     int    21H
     endm

;                                  Function Request 3EH
CLOSE_HANDLE  macro  handle
     mov    bx,handle
     mov    ah,3EH
     int    21H
     endm

;                                  Function Request 3FH
READ_HANDLE  macro  handle,buffer,bytes
     mov    bx,handle
     mov    dx,offset buffer
     mov    cx,bytes
     mov    ah,3FH
     int    21H
     endm
```

```
;                                   Function Request 40H
WRITE_HANDLE  macro  handle,buffer,bytes
     mov    bx,handle
     mov    dx,offset buffer
     mov    cx,bytes
     mov    ah,40H
     int    21H
     endm

;                                   Function Request 41H
DELETE_ENTRY  macro  path
     mov    dx,offset path
     mov    ah,41H
     int    21H
     endm

;                                   Function Request 42H
MOVE_PTR  macro  handle,high,low,method
     mov    bx,handle
     mov    cx,high
     mov    dx,low
     mov    al,method
     mov    ah,42H
     int    21H
     endm

;                                   Function Request 43H
CHANGE_MODE  macro  path,action,attrib
     mov    dx,offset path
     mov    al,action
     mov    cx,attrib
     mov    ah,43H
     int    21H
     endm

;                                   Function Request 4400H,01H
IOCTL_DATA  macro  code,handle
     mov    bx,handle
     mov    al,code
     mov    ah,44H
     int    21H
     endm

;                                   Function Request 4402H,03H
IOCTL_CHAR  macro  code,handle,buffer
     mov    bx,handle
     mov    dx,offset buffer
     mov    al,code
     mov    ah,44H
     int    21H
     endm

;                                   Function Request 4404H,05H
IOCTL_STATUS  macro  code,drive,buffer
     mov    bl,drive
     mov    dx,offset buffer
     mov    al,code
     mov    ah,44H
     int    21H
     endm

;                                   Function Request 4406H,07H
IOCTL_STATUS macro  code,handle
```

```
     mov    bx,handle
     mov    al,code
     mov    ah,44H
     int    21H
     endm

;                                    Function Request 4408H
IOCTL_CHANGE  macro  drive
     mov    bl,drive
     mov    al,08H
     mov    ah,44H
     int    21H
     endm

;                                    Function Request 4409H
IOCTL_RBLOCK  macro  drive
     mov    bl,drive
     mov    al,09H
     mov    ah,44H
     int    21H
     endm

;                                    Function Request 440AH
IOCTL_RHANDLE  macro  handle
     mov    bx,handle
     mov    al,0AH
     mov    ah,44H
     int    21H
     endm

;                                    Function Request 440BH
IOCTL_RETRY  macro  retries,wait
     mov    dx,retries
     mov    cx,wait
     mov    al,0BH
     mov    ah,44H
     int    21H
     endm

;                                    Function Request 440CH
GENERIC_IOCTL_HANDLES macro handle,function,category,buffer
     mov    ch,05H
     mov    cl,function
     mov    dx,offset buffer
     mov    bx,handle
     mov    ah,44H
     mov    al,0CH
     int    21H
     endm

;                                    Function Request 440DH
GENERIC_IOCTL_BLOCK macro drive_num,function,category,parm_blk
     mov    ch,08H
     mov    cl,function
     mov    dx,offset parm_blk - 1
     mov    bx,drive_num
     mov    ah,44H
     mov    al,0DH
     int    21H
     endm

;                                    Function Request 440EH
IOCTL_GET_DRIVE_MAP macro   logical_drv
     mov    bx,logical_drv
```

```
     mov    ah,44H
     mov    al,0EH
     int    21H
     endm

;                                    Function Request 440FH
IOCTL_SET_DRIVE_MAP macro   logical_drv
     mov    bx,logical_drv
     mov    ah,44H
     mov    al,0FH
     int    21H
     endm

;                                    Function Request 45H
XDUP  macro  handle
     mov    bx,handle
     mov    ah,45H
     int    21H
     endm

;                                    Function Request 46H
XDUP2  macro  handle1,handle2
     mov    bx,handle1
     mov    cx,handle2
     mov    ah,46H
     int    21H
     endm

;                                    Function Request 47H
GET_DIR  macro  drive,buffer
     mov    dl,drive
     mov    si,offset buffer
     mov    ah,47H
     int    21H
     endm

;                                    Function Request 48H
ALLOCATE_MEMORY  macro  bytes
     mov    bx,bytes
     mov    cl,4
     shr    bx,cl
     inc    bx
     mov    ah,48H
     int    21H
     endm

;                                    Function Request 49H
FREE_MEMORY  macro  seg_addr
     mov    ax,seg_addr
     mov    es,ax
     mov    ah,49H
     int    21H
     endm

;                                    Function Request 4AH
SET_BLOCK  macro  last_byte
     mov    bx,offset last_byte
     mov    cl,4
     shr    bx,cl
     add    bx,17
     mov    ah,4AH
     int    21H
     mov     ax,bx
     shl     ax,cl
```

```
     dec     ax
     mov     sp,ax
     mov     bp,sp
     endm

;                                    Function Request 4B00H
EXEC macro  path,command,parms
     mov    dx,offset path
     mov    bx,offset parms
     mov    word ptr parms[02h],offset command
     mov    word ptr parms[04h],cs
     mov    word ptr parms[06h],5ch
     mov    word ptr parms[08h],es
     mov    word ptr parms[0ah],6ch
     mov    word ptr parms[0ch],es
     mov    al,0
     mov    ah,4BH
     int    21H
     endm

;                                    Function Request 4B03H
EXEC_OVL  macro  path,parms,seg_addr
      mov    dx,offset path
      mov    bx,offset parms
      mov    parms,seg_addr
      mov    parms[02H],seg_addr
      mov    al,3
      mov    ah,4BH
      int    21H
      endm

;                                    Function Request 4CH
END_PROCESS   macro  return_code
             mov    al,return_code
             mov    ah,4CH
             int    21H
             endm

;                                    Function Request 4DH
RET_CODE macro
      mov    ah,4DH
      int    21H
      endm

;                                    Function Request 4EH
FIND_FIRST_FILE  macro  path,attrib
     mov    dx,offset path
     mov    cx,attrib
     mov    ah,4EH
     int    21H
     endm

;                                    Function Request 4FH
FIND_NEXT_FILE  macro
     mov    ah,4FH
     int    21H
     endm

;                                    Function Request 54H
GET_VERIFY  macro
     mov    ah,54H
     int    21H
     endm
```

```
;                                   Function Request 56H
RENAME_FILE  macro  old_path,new_path
     mov    dx,offset old_path
     push   ds
     pop    es
     mov    di,offset new_path
     mov    ah,56H
     int    21H
     endm

;                                   Function Request 57H
GET_SET_DATE_TIME  macro  handle,action,time,date
     mov    bx,handle
     mov    al,action
     mov    cx,word ptr time
     mov    dx,word ptr date
     mov    ah,57H
     int    21H
     endm

;                                   Function Request 58H
ALLOC_STRAT  macro  code,strategy
     mov    bx,strategy
     mov    al,code
     mov    ah,58H
     int    21H
     endm

;                                   Function Request 59H
GET_ERROR  macro
     mov    ah,59
     int    21H
     endm

;                                   Function Request 5AH
CREATE_TEMP  macro  pathname,attrib
     mov    cx,attrib
     mov    dx,offset pathname
     mov    ah,5AH
     int    21H
     endm

;                                   Function Request 5BH
CREATE_NEW  macro  pathname,attrib
     mov    cx,attrib
     mov    dx,offset pathname
     mov    ah,5BH
     int    21H
     endm

;                                   Function Request 5C00H
LOCK        macro  handle,start,bytes
     mov    bx,handle
     mov    cx,word ptr start
     mov    dx,word ptr start+2
     mov    si,word ptr bytes
     mov    di,word ptr bytes+2
     mov    al,0
     mov    ah,5CH
     int    21H
     endm

;                                   Function Request 5C01H
UNLOCK      macro  handle,start,bytes
```

```
     mov    bx,handle
     mov    cx,word ptr start
     mov    dx,word ptr start+2
     mov    si,word ptr bytes
     mov    di,word ptr bytes+2
     mov    al,1
     mov    ah,5CH
     int    21H
     endm

;                                    Function Request 5E00H
GET_MACHINE_NAME  macro  buffer
     mov    dx,offset buffer
     mov    al,0
     mov    ah,5EH
     int    21H
     endm

;                                    Function Request 5E02H
PRINTER_SETUP  macro  index,lgth,string
     mov    bx,index
     mov    cx,lgth
     mov    dx,offset string
     mov    al,2
     mov    ah,5EH
     int    21H
     endm

;                                    Function Request 5F02H
GET_LIST    macro  index,local,remote
     mov    bx,index
     mov    si,offset local
     mov    di,offset remote
     mov    al,2
     mov    ah,5FH
     int    21H
     endm

;                                    Function Request 5F03H
REDIR       macro  device,value,source,destination
     mov    bl,device
     mov    cx,value
     mov    si,offset source
     mov    es,seg destination
     mov    di,offset destination
     mov    al,03H
     mov    ah,5FH
     int    21H
     endm

;                                    Function Request 5F04H
CANCEL_REDIR  macro  local
     mov    si,offset local
     mov    al,4
     mov    ah,5FH
     int    21H
     endm

;                                    Function Request 62H
GET_PSP     macro
     mov    ah,62H
     int    21H
     endm
;
```

```
;
;******************
; General
;******************
;
DISPLAY_ASCIIZ  macro  asciiz_string
     local  search,found_it
     mov    bx,offset asciiz_string

search:
     cmp    byte ptr [bx],0
     je     found_it
     inc    bx
     jmp short search

found_it:
     mov    byte ptr [bx],"$"
     display asciiz_string
     mov    byte ptr [bx],0
     display_char 0DH
     display_char 0AH
     endm

;
MOVE_STRING  macro  source,destination,count
     push   es
     push   ds
     pop    es
     assume es:code
     mov    si,offset source
     mov    di,offset destination
     mov    cx,count
 rep movs   es:destination,source
     assume es:nothing
     pop    es
     endm

;
CONVERT  macro  value,base,destination
     local  table,start
     jmp    start
table  db   "0123456789ABCDEF"

start:
     push   ax
     push   bx
     push   dx
     mov    al,value
     xor    ah,ah
     xor    bx,bx
     div    base
     mov    bl,al
     mov    al,cs:table[bx]
     mov    destination,al
     mov    bl,ah
     mov    al,cs:table[bx]
     mov    destination[1],al
     pop    dx
     pop    bx
     pop    ax
     endm

;
CONVERT_TO_BINARY  macro  string,number,value
```

```
     local  ten,start,calc,mult,no_mult
     jmp    start
ten  db     10

start:
     mov    value,0
     xor    cx,cx
     mov    cl,number
     xor    si,si

calc:
     xor    ax,ax
     mov    al,string[si]
     sub    al,48
     cmp    cx,2
     jl     no_mult
     push   cx
     dec    cx

mult:
     mul    cs:ten
     loop   mult
     pop    cx

no_mult:
     add    value,ax
     inc    si
     loop   calc
     endm

;
CONVERT_DATE  macro  dir_entry
     mov    dx,word ptr dir_entry[24]
     mov    cl,5
     shr    dl,cl
     mov    dh,dir_entry[24]
     and    dh,1FH
     xor    cx,cx
     mov    cl,dir_entry[25]
     shr    cl,1
     add    cx,1980
     endm

;
PACK_DATE  macro  date
     local set_bit
;
; On entry: DH=day, DL=month, CX=(year-1980)
;
     sub   cx,1980
     push  cx
     mov   date,dh
     mov   cl,5
     shl   dl,cl
     pop   cx
     jnc   set_bit
     or    cl,80h

set_bit:
     or    date,dl
     rol   cl,1
     mov   date[1],cl
     endm
;
```

Chapter 2 MS-DOS Device Drivers

.....

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2.12 Two Sample Device Drivers

2.1 Introduction

The io.sys file comprises the "resident" device drivers, which form the MS-DOS BIOS. These drivers are called upon by MS-DOS to handle input/output (I/O) requests initiated by application programs.

One of the most powerful features of MS-DOS is the ability to add new devices such as printers, plotters, and mouse input devices without rewriting the BIOS. The MS-DOS BIOS is configurable; that is, new drivers can be added and existing drivers can be preempted. Nonresident, or installable, device drivers may be easily added at boot time by including a device command line in the config.sys file.

At boot time, a minimum of five resident device drivers must be present. These drivers are in a linked list: the header of each one contains a DWORD pointer to the next. The last driver in the chain has an end-of-list marker of -1, -1 (all bits on).

Each driver in the chain has two entry points: the strategy entry point and the interrupt entry point. MS-DOS does not take advantage of the two entry points: it calls the strategy routine, then immediately calls the interrupt routine.

The dual entry points will accomodate future multitasking versions of MS-DOS and MS OS/2 operating systems. In multitasking environments, I/O must be asynchronous; to accomplish this, the strategy routine will be called to (internally) queue a request and return quickly. It is then the responsibility of the interrupt routine to perform the I/O at interrupt time by getting requests from the internal queue and processing them. When a request is completed, it is flagged as "done" by the interrupt routine. MS-DOS periodically scans the list of requests looking for those that are flagged as done, and "wakes up" the process waiting for the completion of the request.

When requests are queued in this manner, it is no longer sufficient to pass I/O information in registers, since many requests may be pending at any time. Therefore, the MS-DOS device interface uses "packets" to pass request information. These request packets are of variable size and format, and are composed of two parts:

1. The static request header section, which has the same format for all requests

2. A section which has information specific to the type of request

A driver is called with a pointer to a packet. In multitasking versions, this packet will be linked into a global chain of all pending I/O requests maintained by MS-DOS.

MS-DOS does not implement a global or local queue. Only one request is pending at any one time. The strategy routine must store the address of the packet at a fixed location, and the interrupt routine, which is called

immediately after the strategy routine, should process the packet by completing the request and returning. It is assumed that the request is completed when the interrupt routine returns.

To make a device driver that sysinit can install, a .bin (core image) or .exe format file must be created with the device driver header at the beginning of the file. The link field should be initialized to -1 (sysinit fills it in). Device drivers which are part of the BIOS should have their headers point to the next device in the list and the last header should be initialized to -1,-1. The BIOS must be a .bin (core image) format file.

The .exe format installable device drivers may be used in non-IBM versions of MS-DOS. On the IBM Personal Computer, the .exe loader is located in command.com which is not present at the time that installable devices are being loaded.

2.2 Format of a Device Driver

A device driver is a program segment responsible for communication between DOS and the system hardware. It has a special header at the beginning identifying it as a device driver, defining entry points, and describing various attributes of the device.

.....
Note
  For device drivers, the file must not use the ORG 100H (like .com files). Because it does not use the Program Segment Prefix (PSP), the device driver is simply loaded; therefore, the file must have an origin of zero (ORG 0 or no ORG statement).
.....

There are two kinds of device drivers:

- Character device drivers
- Block device drivers

Character devices perform serial character I/O. Examples are the console, communications port and printer. These devices are named (i.e., CON, AUX, CLOCK, etc.), and programs may open channels (handles or file control blocks) to do I/O to them.

Block devices include all the disk drives on the system. They can perform random I/O in structured pieces called blocks (usually the physical sector size). These devices are not named as the character devices are, and therefore cannot be opened directly. Instead they have unit numbers and are identified by drive letters such as A, B, and C.

A single block device driver may be responsible for one or more logically contiguous disk drives. For example, block device driver ALPHA may be responsible for drives A, B, C, and D. This means that it has four units defined (0-3), and therefore, takes up four drive letters. The position of the driver in the list of all drivers determines which units correspond to which driver letters. If driver ALPHA is the first block driver in the device list, and it defines four units (0-3), then they will be A, B, C, and D. If BETA is the second block driver and defines three units (0-2), then they will be E, F, and G, and so on. The theoretical limit is 63, but it should be noted that the device installation code will not allow the installation of a device if it would result in a drive letter greater than Z (5AH). All block device drivers present in the standard resident BIOS will be placed ahead of installable block device drivers in the list.

.....
Note
  Because they have only one name, character devices cannot define
  multiple units.
.....

2.3 How to Create a Device Driver

To create a device driver that MS-DOS can install, you must create a binary file (.com or .exe format) with a device header at the beginning of the file. Note that for device drivers, the code should not be originated at 100H, but at 0. The device header contains a link field (a pointer to the next device header) which should be -1, unless there is more than one device driver in the file. The attribute field and entry points must be set correctly.

If it is a character device, the name field should be filled in with the name of that character device. The name can be any legal eight-character filename. If the name is less than eight characters, it should be padded out to eight characters with spaces (20H). Note that device names do not include colons (:). The fact that CON is the same as CON: is a property of the default MS-DOS command interpreter (command.com) and not of the device driver or the MS-DOS interface. All character device names are handled in this way.

MS-DOS always processes installable device drivers before handling the default devices, so to install a new CON device, simply name the device CON. Remember to set the standard input device and standard output device bits in the attribute word on a new CON device. The scan of the device list stops on the first match, so the installable device driver takes precedence.

It is not possible to replace the resident disk block device driver with an installable device driver the same way you can replace the other device drivers in the BIOS. Block drivers can be used only for devices not directly supported by the default disk drivers in the io.sys file.

.....
Note
  Because MS-DOS can install the driver anywhere in memory, care must be
  taken when making far memory references. You should not expect that your
  driver will always be loaded in the same place every time.
.....

2.3.1 Device Strategy Routine

The device strategy routine, which is called by MS-DOS for each device driver service request, is primarily responsible for queuing these requests in the order in which they are to be processed by the device interrupt routine. Such queuing can be a very important performance feature in a multitasking environment, or where asynchronous I/O is supported. As MS-DOS does not currently support these facilities, only one request can be serviced at a time, and this routine is usually very short. In the coding examples in Section 2.12, "Two Sample Device Drivers," each request is simply stored in a single pointer area.

2.3.2 Device Interrupt Routine

The device interrupt routine contains the code necessary to process

the service request. It may interface to the hardware, or it may use ROM BIOS calls. It usually consists of a series of procedures that handle the specific command codes to be supported as well as some exit and error-handling routines. See the coding examples in Section 2.12, "Two Sample Device Drivers."

2.4 Installing Device Drivers

MS-DOS allows new device drivers to be installed dynamically at boot time. This is accomplished by initialization code in the io.sys file that reads and processes the config.sys file.

MS-DOS calls upon the device drivers to perform their function in the following manner:

1. MS-DOS makes a FAR call to the strategy entry.

2. MS-DOS passes device driver information in a request header to the strategy routine.

3. MS-DOS makes a FAR call to the interrupt entry.

This calling structure is designed to be easily upgraded to support any future multitasking environment.

2.5 Device Headers

A device header is required at the beginning of a device driver. A device header looks like this:

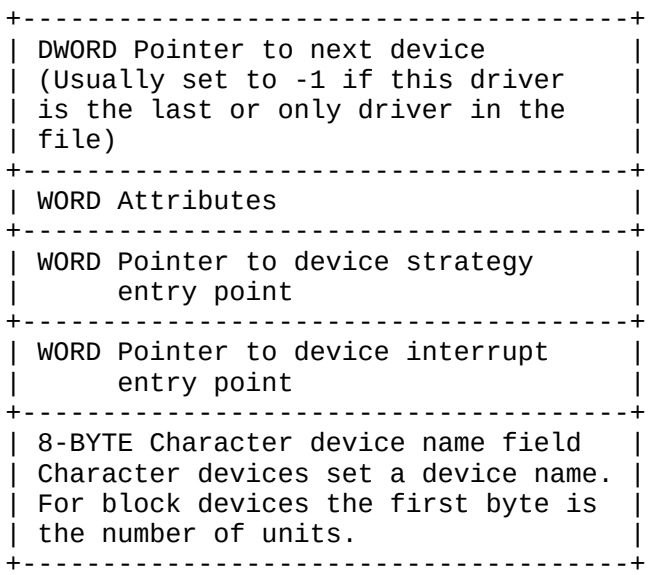


Figure 2.1 Sample Device Header

Note that the device entry points are words. They must be offsets from the same segment number used to point to this table. For example, if xxx:yyy points to the start of this table, then xxx:strategy and xxx:interrupt are the entry points.

The device header fields are described in the following section.

2.5.1 Pointer to Next Device Field

The pointer to the next device header field is a double-word field (offset followed by segment) that is set by MS-DOS to point at the next driver in the system list at the time the device driver is loaded. It is important that this field be set to -1 prior to load (when it is on the disk as a file) unless there is more than one device driver in the file. If there is more than one driver in the file, the first word of the double-word pointer should be the offset of the next driver's device header.

.....
Note
  If there is more than one device driver in the file, the last driver in the file must have the pointer to the next device header field set to -1.
.....

2.5.2 Attribute Field

The attribute field is used to identify the type of device for which this driver is responsible. In addition to distinguishing between block and character devices, these bits are used to give selected character devices special treatment. (Note that if a bit in the attribute word is defined only for one type of device, a driver for the other type of device must set that bit to 0.)

Table 2.1
For Character Devices:

Bit	Value	Meaning
Bit	Value	Meaning
0	1	Device is console input (sti) device
1	1	Device is console output (sto) device
2	1	Device is nul device
3	1	Device is clock device
4-5		Reserved (must be 0)
6	1	Device supports 3.2 functions
7-10		Reserved (must be 0)
11	1	Device understands Open/Close
12		Reserved (must be 0)
13	1	Device supports Output Until Busy (OUB)
14	1	Device supports IOCtl control strings
15	1	Character device

Table 2.2
For Block Devices:

Bit	Value	Meaning
Bit	Value	Meaning
0-5		Reserved (must be 0)
6	1	Device supports 3.2 functions and Generic IOCtl function calls
7-10		Reserved (must be 0)

11	1	Device understands Open/Close/Removable Media
12		Reserved (must be 0)
13	1	Device determines the media by examining the FATID byte
14	1	Device supports IOCtl control strings
15	0	Block device

For example, assume that you have a new device driver that you want to use as the standard input and output. In addition to installing the driver, you must tell MS-DOS that you want the new driver to override the current standard input and standard output (the CON device). This is accomplished by setting the attributes to the desired characteristics, so you would set bits 0 and 1 to 1 (note that they are separate). Similarly, a new CLOCK device could be installed by setting that attribute. (Refer to Section 2.10, "The Clock Device," in this chapter for more information.) Although there is a NUL device attribute, the NUL device cannot be reassigned. This attribute exists so that MS-DOS can determine if the NUL device is being used.

Bit 13 for block devices affects the operation of the Build BPB (BIOS Parameter Block) device call. If set, it requires the first sector of the FAT always to reside in the same place. This bit has a different meaning on character devices. It indicates that the device implements the Output Until Busy device call.

The IOCtl bit (bit 14) has meaning on character and block devices. The IOCtl functions allow data to be sent and received by the device for its own use (to set baud rate, stop bits, form length, etc.) instead of passing data over the device channel as a normal read or write does. The interpretation of the passed information is up to the device but it must not be treated as normal I/O. This bit tells MS-DOS whether the device can handle control strings by using the IOCtl system call, Function 44H.

If a driver cannot process control strings, it should initially set this bit to 0. This tells MS-DOS to return an error if an attempt is made (via Function 44H) to send or receive control strings to this device. A device which can process control strings should initialize the IOCtl bit to 1. For drivers of this type, MS-DOS will make calls to the IOCtl input and output device functions to send and receive IOCtl strings.

The IOCtl functions allow data to be sent and received by the device for its own use (for example, to set baud rate, stop bits, and form length), instead of passing data over the device channel as does a normal read or write. The interpretation of the passed information is up to the device, but it must not be treated as a normal I/O request.

The Open/Close/Removable Media bit (bit 11) signals to MS-DOS 3.x and later versions whether this driver supports additional MS-DOS 3.x functionality. To support these old drivers, it is necessary to detect them. This bit was reserved in MS-DOS 2.x, and is 0. All new devices should support the Open, Close, and Removable Media calls and set this bit to 1. Since MS-DOS 2.x never makes these calls, the driver will be backward-compatible.

The MS-DOS 3.2 bit (bit 6) signals whether the device supports logical drive mapping via Function 440EH (Get Logical Drive Map) and Function 440FH (Set Logical Drive Map). This bit also supports generic IOCtl functions via Function 440CH (Generic IOCtl for Handles) and Function 440DH (Generic

IOCtl for Block Devices).

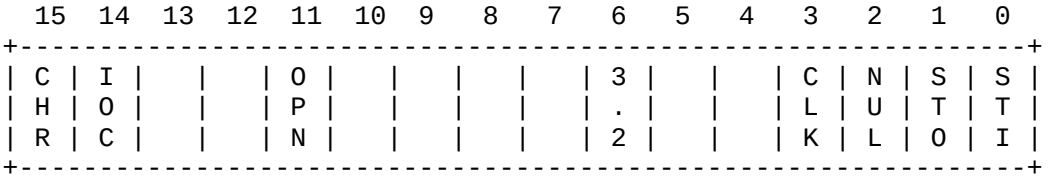


Figure 2.2 Attribute Word for Character Devices

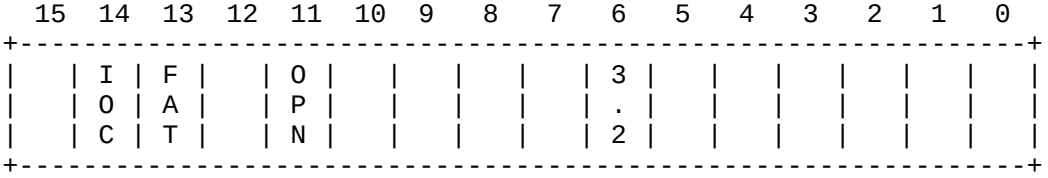


Figure 2.3 Attribute Word for Block Devices

2.5.3 Strategy and Interrupt Routines

These two fields are the pointers to the entry points of the strategy and interrupt routines. They are word values, so they must be in the same segment as the device header.

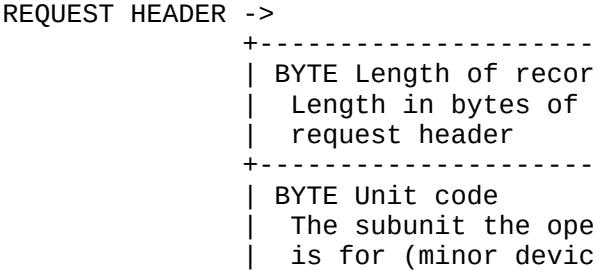
2.5.4 Name Field

This is an eight-byte field that contains the name of a character device or the number of units of a block device. If the field refers to a block device, the number of units can be put in the first byte. This is optional, because MS-DOS will fill in this location with the value returned by the driver's Init code. For more information, see Section 2.4, "Installing Device Drivers."

2.6 Request Header

When MS-DOS calls a device driver to perform a function, it passes a request header in ES:BX to the strategy entry point. This is a fixed length header, followed by data pertinent to the operation being performed. Note that it is the device driver's responsibility to preserve the machine state (for example, save all registers, including flags, on entry, and restore them on exit). There is enough room on the stack when the strategy or interrupt routine is called to do about 20 pushes. If more room on the stack is needed, the driver should set up its own stack.

The following figure illustrates a request header.



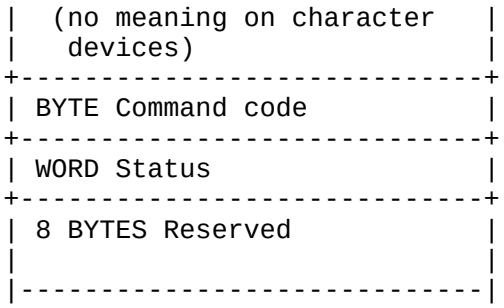


Figure 2.4 Request Header

The request header fields are described below.

2.6.1 Length of Record

This field contains the length (in bytes) of the request header.

2.6.2 Unit Code Field

The unit code field identifies which unit in your device driver the request is for. For example, if your device driver has three units defined, then the possible values of the unit code field would be 0, 1, and 2.

2.6.3 Command Code Field

The command code field in the request header can have the following values:

Code	Function
0	Init
1	Media Check (Block devices only)
2	Build BPB (Block devices only)
3	IOCtl Input (Only called if device has IOCtl)
4	Input (Read)
5	Non-destructive Read, No Wait (Character devices only)
6	Input Status (Character devices only)
7	Input Flush (Character devices only)
8	Output (Write)
Code	Function
#8	Output (Write)
9	Output (Write) with Verify
10	Output Status (Character devices only)
11	Output Flush (Character devices only)
12	IOCtl Output (Only called if device has IOCtl)

13 Device Open (Only called if Open/Close/Removable Media bit set)

14 Device Close (Only called if Open/Close/Removable Media bit set)

15 Removable Media (Only called if Open/Close/Removable Media bit set and device is block)

16 Output Until Busy (Only called if bit 13 is set on character devices)

Code	Function
#	
19	Generic IOCtl Request
23	Get Logical Device
24	Set Logical Device

2.6.4 Status Field

The following figure illustrates the status field in the request header.

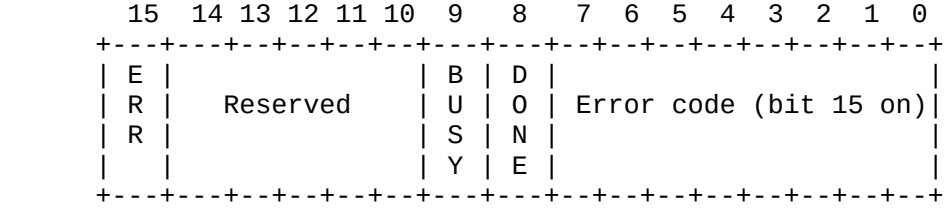


Figure 2.5 Status Field

The status word is zero on entry and is set by the driver interrupt routine on return.

Bit 8 is the done bit. When set, it means the operation has completed. The driver sets it to 1 when it exits.

Bit 15 is the error bit. If it is set, then the low eight bits indicate the error. The errors are as follows:

Error	Meaning
0	Write protect violation
1	Unknown unit
2	Drive not ready
3	Unknown command
4	CRC error
5	Bad drive request structure length
6	Seek error
7	Unknown media
8	Sector not found
9	Printer out of paper
A	Write fault
B	Read fault
C	General failure
D	Reserved
E	Reserved
F	Invalid disk change

Bit 9 is the busy bit, which is set only by Status calls and the

Removable Media call.

2.7 Device Driver Functions

Device drivers may perform all or some of these general functions. In some cases, these functions break down into several command codes, for specific cases. Each of the following general functions is described in this section.

- Init
- Media Check
- Build BPB
- Read, or Write, or Write Until Busy, or Write with Verify, or Read IOCtl, or Write IOCtl
- Non-destructive Read, No Wait
- Open or Close (3.x)
- Removable Media (3.x)
- Status
- Flush
- Generic IOCtl
- Get or Set Logical Device

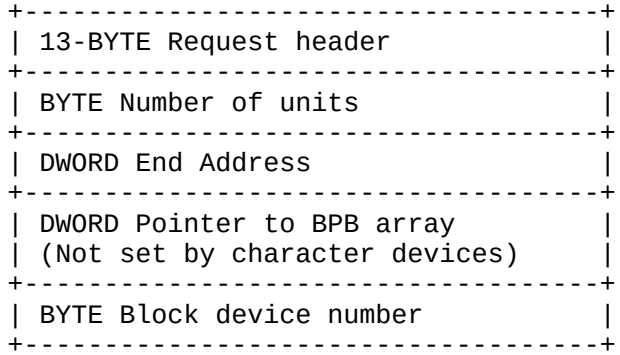
All strategy routines are called with ES:BX pointing to the request header. The interrupt routines get the pointers to the request header from the queue that the strategy routines store them in. The command code in the request header tells the driver which function to perform and what data follows the request header.

.....
Note
  All DWORD pointers are stored offset first, then segment.
.....

2.7.1 The Init Function

Command code = 0

INIT - ES:BX ->



One of the functions defined for each device driver is Init. This routine is called only once when the device is installed. The Init routine must return the end address, which is a DWORD pointer to the end of the portion of the device driver to remain resident. To save space, you can use this pointer method to delete initialization code that is needed only once.

The number of units, end address, and BPB pointer are to be set by the driver. However, on entry for installable device drivers, the DWORD that is to be set by the driver to the BPB array (on block devices) points to the character after the "=" on the line in config.sys that caused this device driver to be loaded. This allows drivers to scan the config.sys invocation line for parameters that might be passed to the driver. This line is terminated by a RETURN or a linefeed character. This data is read-only and allows the device to scan the config.sys command line for arguments.

```
device=\dev\vt52.sys /l
       |
       |_____BPB address points here
```

Also, for block devices only, the drive number assigned to the first unit defined by this driver (A=0) as contained in the block device number field. This is also read-only.

.....
Note
  The Init routine can issue only Functions 01H-0CH, 25H, 30H, and 35H.
.....

For installable character devices, the end address parameter must be returned. This is a pointer to the first available byte of memory above the driver and may be used to throw away initialization code.

Block devices must return the following information:

1. The number of units must be returned. MS-DOS uses this number to determine logical device names. If the current maximum logical device letter is F at the time of the install call, and the Init routine returns 4 as the number of units, then they will have logical names G, H, I, and J. This mapping is determined by the position of the driver in the device list, and by the number of units on the device (stored in the first byte of the device name field).

2. A DWORD pointer to an array of word offsets (pointers) to BPBs (BIOS Parameter Blocks) must be returned. The BPBs passed by the device driver are used by MS-DOS to create an internal structure. There must be one entry in this array for each unit defined by the device driver. In this way, if all units are the same, all the pointers can point to the same BPB, saving space. If the device driver defines two units, then the DWORD pointer points to the first of two one-word offsets which in turn point to BPBs. The format of the BPB is described later in this chapter in Section 2.7.3, "The Build BPB Function."

   Note that this array of word offsets must be protected (below the free pointer set by the return), since an internal DOS structure will be built starting at the byte pointed to by the free pointer. The defined sector size must be less than or equal to the maximum sector size defined by the resident device drivers (BIOS) during initialization. If it isn't, the installation will fail.

3. The last thing that the Init function of a block device must pass back is the media descriptor byte. This byte means nothing to

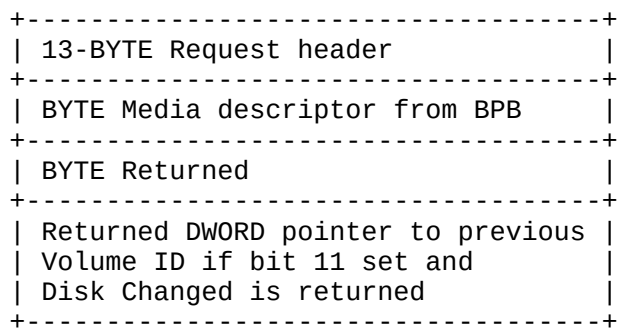
MS-DOS, but is passed to devices so that they know what parameters MS-DOS is currently using for a particular drive.

.....
Note
  If there are multiple device drivers in a single file, MS-DOS uses the ending address returned by the last Init function called. All device drivers in a single file should return the same ending address. All devices in a single file should be grouped together low in memory with the initialization code for all devices following it in memory.
.....

2.7.2 The Media Check Function

Command Code = 1

MEDIA CHECK - ES:BX ->



The Media Check function is used only with block devices. It is called when there is a pending drive-access call other than a file read or write, such as Open, Close, delete, and rename. Its purpose is to determine whether the media in the drive has been changed. If the driver can assure that the media has not been changed (through a door-lock or other interlock mechanism), MS-DOS performance is enhanced, because MS-DOS does not need to reread the FAT and invalidate in-memory buffers for each directory access.

When a disk-access call to the DOS occurs (other than a file read or write), the following sequence of events takes place:

1. The DOS converts the drive letter into a unit number of a particular block device.

2. The device driver is then called to request a media check on that subunit to see if the disk might have been changed. MS-DOS passes the old media descriptor byte. The driver returns one of the following:

Return	Meaning
(1)	Media not changed
(0)	Don't know if changed
(-1)	Media changed
value	Error (value is a standard error code value)

   If the media has not been changed, MS-DOS proceeds with the disk access.

   If the value returned is -1, then if there are any disk sectors that have been modified and not written back out to the disk for this unit, MS-DOS assumes that the disk has not been changed and proceeds. MS-DOS invalidates any other buffers for the unit and does a Build BPB call (see Step 3, following).

If the media has been changed, MS-DOS invalidates all buffers associated with this unit including buffers with modified data that are waiting to be written, and requests a new BIOS Parameter Block via the Build BPB call (see Step 3).

3. Once the BPB has been returned, MS-DOS corrects its internal structure for the drive from the new BPB and proceeds with the access after reading the directory and the FAT.

Note that the previous media ID byte is passed to the device driver. If the old media ID byte is the same as the new one, the disk might have been changed and a new disk may be in the drive; therefore, all FAT, directory, and data sectors that are buffered in memory for the drive are considered invalid.

If the driver has bit 11 of the device attribute word set to 1, and the driver returns -1 (Media Changed) the driver must set the DWORD pointer to the previous Volume ID field. If the DOS determines that "Media changed" is an error based on the state of the DOS buffer cache, the DOS will generate a 0FH error on behalf of the device. If the driver does not implement volume ID support, but has bit 11 set, (it should set a static pointer to the string "NO NAME" ,0.)

It is not possible for a user to change a disk in less than two seconds. So when Media Check occurs within two seconds of a disk access, the driver reports "Media not changed (1)." This improves performance tremendously.

.....
Note
  If the media ID byte in the returned BPB is the same as the previous media ID byte, MS-DOS will assume that the format of the disk is the same (even though the disk may have been changed) and will skip the step of updating its internal structure. Therefore, all BPBs must have unique media bytes regardless of FAT ID bytes.
.....

2.7.3 The Build BPB Function

Command code = 2

BUILD BPB - ES:BX ->

13-BYTE Request header
BYTE Media descriptor from BPB
DWORD Transfer address (Points to one sector worth of scratch space or first sector of FAT depending on the value of Bit 13 in the device attribute word.)
DWORD Pointer to BPB

The Build BPB function is used with block devices only. As described in the Media Check function, the Build BPB function will be called any time that a preceding Media Check call indicates that the disk has been or might have been changed. The device driver must return a pointer to a BPB. This is different from the Init call where the device driver returns a pointer

to an array of word offsets to BPBs.

The Build BPB call gets a DWORD pointer to a one-sector buffer. The contents of this buffer are determined by the non-FAT ID bit (bit 13) in the attribute field. If the bit is zero, then the buffer contains the first sector of the first FAT. The FAT ID byte is the first byte of this buffer. In this case, the driver must not alter this buffer. Note that the location of the FAT must be the same for all possible media because this first FAT sector must be read before the actualBPB is returned. If the non-FAT ID bit is set, the pointer points to one sector of scratch space (which may be used for anything). For information on how to construct the BPB, see Section 2.8, "The Media Descriptor Byte," and Section 2.9, "Format of a Media Descriptor Table."

MS-DOS 3.x includes additional support for devices that have door-locks or some other means of telling when a disk has been changed. There is a new error that can be returned from the device driver (error 15). The error means "the disk has been changed when it shouldn't have been," and the user is prompted for the correct disk using a volume ID. The driver may generate this error on read or write. The DOS may generate the error on Media Check calls if the driver reports media changed, and there are buffers in the DOS buffer cache that need to be flushed to the previous disk.

For drivers that support this error, the Build BPB function is a trigger that causes a new volume ID to be read off the disk. This action indicates that the disk has been legally changed. A volume ID is placed on a disk by the format command, and is simply an entry in the root directory of the disk that has the Volume ID attribute. It is stored by the driver as an ASCIZ string.

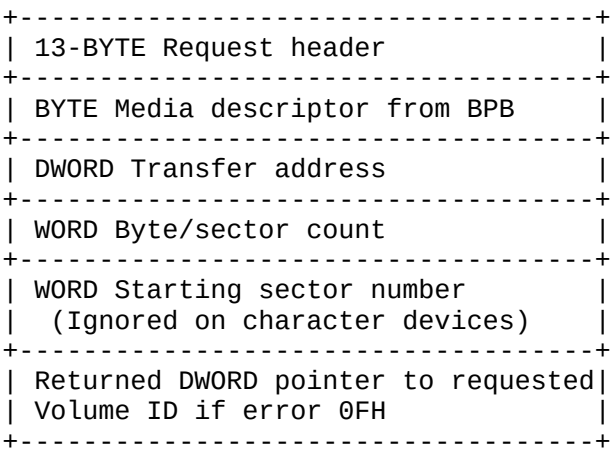
The requirement that the driver return a volume ID does not exclude some other volume identifier scheme as long as the scheme uses ASCIZ strings. A NUL (nonexistent or unsupported) volume ID is by convention the following string:

```
DB     "NO NAME     ",0
```

2.7.4 The Read or Write Function

Command codes = 3,4,8,9,12, and 16

READ OR WRITE (Including IOCtl) or
OUTPUT UNTIL BUSY - ES:BX ->



Code	Request
3	IOCtl read
4	Read (block or character device)

8 Write (block or character device)
9 Write with Verify
12 IOCtl Write
16 Output Until Busy (character device only)

The driver must perform the Read or Write call depending on which command code is set. Block devices read or write sectors; character devices read or write bytes.

When I/O completes, the device driver must set the status word and report the number of sectors or bytes successfully transferred. This should be done even if an error prevented the transfer from being completed. Setting the error bit and error code alone is not sufficient.

In addition to setting the status word, the driver must set the sector count to the actual number of sectors (or bytes) transferred. No error check is performed on an IOCtl I/O call. The device driver must always set the return byte/sector count to the actual number of bytes/sectors successfully transferred.

If the verify switch is on, the device driver will be called with command code 9 (Write with Verify). Your device driver will be responsible for verifying the write.

If the driver returns error code 0FH (Invalid disk change), it must return a DWORD pointer to an ASCIZ string (which is the correct volume ID). Returning this error code triggers the DOS to prompt the user to re-insert the disk. The device driver should have read the volume ID as a result of the Build BPB function.

Drivers may maintain a reference count of open files on the disk by monitoring the Open and Close functions. This allows the driver to determine when to return error 0FH. If there are no open files (reference count = 0), and the disk has been changed, the I/O is okay. If there are open files, however, an 0FH error may exist.

The Output Until Busy call is a speed optimization on character devices only for print spoolers. The device driver is expected to output all the characters possible until the device returns busy. Under no circumstances should the device driver block during this function. Note that it is not an error for the device driver to return the number of bytes output as being less than the number of bytes requested (or = 0).

The Output Until Busy call allows spooler programs to take advantage of the "burst" behavior of most printers. Many printers have on-board RAM buffers that typically hold a line or a fixed amount of characters. These buffers fill up without the printer going busy, or going busy for a short period (less than ten instructions) between characters. A line of characters can be quickly output to the printer, after which the printer is busy for a long time while the characters are being printed. This new device call allows background spooling programs to use this burst behavior efficiently. Rather than take the overhead of a device driver call for each character, or risk getting stuck in the device driver outputting a block of characters, this call allows a burst of characters to be output without the device driver having to wait for the device to be ready.

The Following Applies to Block Device Drivers:

Under certain circumstances, the BIOS may be asked to perform a write operation of 64K bytes, which seems to be a "wrap-around" of the transfer address in the BIOS I/O packet. This request, which arises due to an optimization added to the write code in MS-DOS, will manifest itself only on user writes that are within a sector size of 64K bytes on files

"growing" past the current end-of-file (EOF) mark. It is allowable for the BIOS to ignore the balance of the write that "wraps around" if it so chooses. For example, a write of 10000H bytes worth of sectors with a transfer address of xxx:1 could ignore the last two bytes. A user program can never request an I/O of more than FFFFH bytes and cannot wrap around (even to 0) in the transfer segment. Therefore, in this case, the last two bytes can be ignored.

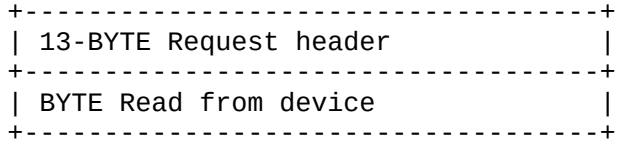
MS-DOS maintains two FATs. If the DOS has problems reading the first, it automatically tries the second before reporting the error. The BIOS is responsible for all retries.

Although the command.com handler does no automatic retries, there are applications that have their own Interrupt 24H handlers that do automatic retries on certain types of Interrupt 24H errors before reporting them.

2.7.5 The Non-destructive Read, No Wait Function

Command code = 5

NON-DESTRUCTIVE READ NO WAIT - ES:BX ->



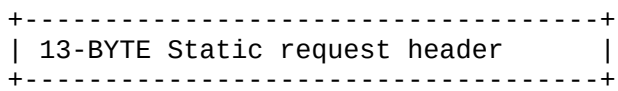
The Non-destructive Read, No Wait function allows MS-DOS to look ahead one input character. The device sets the done bit in the status word.

If the character device returns busy bit = 0 (there are characters in the buffer), then the next character that would be read is returned. This character is not removed from the input buffer (hence the term "Non-destructive Read"). If the character device returns busy bit = 1, there are no characters in the buffer.

2.7.6 The Open or Close Function

Command codes = 13 and 14

OPEN or CLOSE - ES:BX ->



The Open and Close functions are called by MS-DOS 3.x only if the device driver sets the Open/Close/Removable Media attribute bit in the device header. They are designed to inform the device about current file activity on the device. On block devices, they can be used to manage local buffering. The device can keep a reference count. Every Open causes the device to increment the count, every Close to decrement. When the count goes to zero, it means there are no open files on the device, and the device should flush any buffers that have been written to that may have been used inside the device, because it is now "legal" for the user to change the media on a removable media drive.

There are problems with this mechanism on block devices because programs that use FCB calls can open files without closing them. It is therefore advisable to reset the count to zero without flushing the buffers when the answer to "Has the media been changed?" is yes, and the Build BPB call is made to the device.

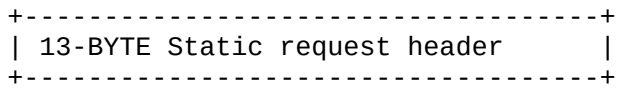
These calls are more useful on character devices. The Open call, for instance, can be used to send a device initialization string. On a printer, this could cause a string for setting font and page size characteristics to be sent to the printer so that it would always be in a known state at the start of an I/O stream. Using IOCtl to set these pre- and post- strings provides a flexible mechanism of serial I/O device stream control. The reference count mechanism can also be used to detect a simultaneous access error. It may be desirable to disallow more than one Open on a device at any given time. In this case, a second Open would result in an error.

Note that since all processes have access to stdin, stdout, stderr, stdaux, and stdprn (handles 0,1,2,3,4), the CON, AUX, and PRN devices are always open.

2.7.7 The Removable Media Function

Command code = 15

REMOVABLE MEDIA - ES:BX ->



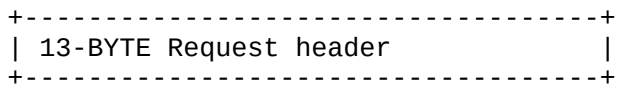
The Removable Media function is called by MS-DOS 3.x only if the device driver sets the Open/Close/Removable Media attribute bit in the device header. This call is given only to block devices by a subfunction of the IOCtl system call. It is sometimes desirable for a utility to know whether it is dealing with a nonremovable media drive (such as a hard disk), or a removable media drive (like a floppy). An example is the format command, which prints different versions of some of the prompts.

The information is returned in the busy bit of the status word. If the busy bit is 1, then the media is nonremovable. If the busy bit is 0, then the media is removable. Note that the error bit is not checked. It is assumed that this call always succeeds.

2.7.8 The Status Function

Command codes = 6 and 10

STATUS Calls ES:BX ->



The Status function returns information to the DOS as to whether data is waiting for input or output. All the driver must do is set the status word and the busy bit as follows:

- For output on character devices--if the driver sets bit 9 to 1 on return, it informs the DOS that a write request (if made) would wait for completion of a current request. If it is 0, there is no current request, and a write request (if made) would start immediately.

- For input on character devices with a buffer--A return of 1 implies that no characters are buffered and that a read request (if made) would go to the physical device. If it is 0 on return, then there are characters in the device buffer and a read would not be blocked. A return of 0 implies that the user has typed something. MS-DOS assumes that all character devices have an input type-ahead buffer.

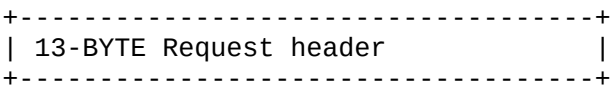
Devices that do not have a type-ahead buffer should always return

busy = 0 so that the DOS will not "hang" waiting for something to get into a nonexistent buffer.

2.7.9 The Flush Function

Command codes = 7 and 11

FLUSH Calls - ES:BX ->



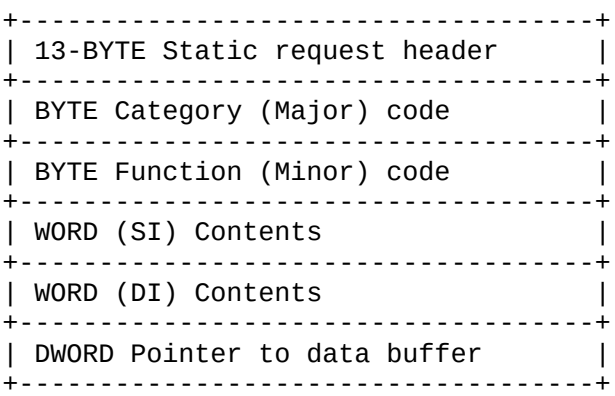
The Flush function tells the driver to flush (terminate) all pending requests. This call is used to flush the input queue on character devices.

The device driver performs the flush function, sets the status word, and returns.

2.7.10 The Generic IOCtl Function

Command code = 19

ES:BX ->



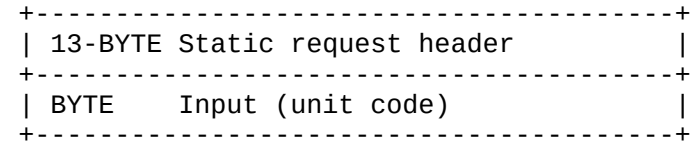
The Generic IOCtl function provides a generic, expandable IOCtl facility that replaces and makes the Read IOCtl and Write IOCtl device driver functions obsolete. The MS-DOS 2.0 IOCtl functions remain to support existing uses of the IOCtl system call (Subfunctions 2, 3, 4, and 5), but new device drivers should use this generic MS-DOS IOCtl facility.

The Generic IOCtl function contains both a category and function code. The DOS examines the category field in order to intercept and obey device commands that are actually serviced by the DOS code; all other command categories are forwarded to the device driver for servicing.

For more information on these category and function codes, refer to Function 440CH (Generic IOCtl for Handles) and Function 440DH (Generic IOCtl for Block Devices) in Chapter 1, "System Calls."

2.7.11 The Get/Set Logical Drive Map Function

Command codes = 23 (Get) or 24 (Set)



```
| BYTE    Output (last device referenced)|
+---------------------------------------+
| BYTE    Command code                  |
+---------------------------------------+
| WORD    Status                        |
+---------------------------------------+
| DWORD   Reserved                      |
+---------------------------------------+
```

The Get/Set Logical Drive Map function is called by MS-DOS only if the device driver sets the DOS 3.2 attribute bit in the device header. The call is issued only to block devices by the subfunction of the IOCtl system call. The logical drive to be mapped is passed in the Unit field of the header to the device driver. The device driver returns the current logical drive owner of the physical device that maps to the requested physical drive. To detect whether a logical device currently owns the physical device to which it is mapped, a program needs to verify that, after a call of Function 440EH or 440FH (Get/Set Logical Drive Map), the value of the Unit field is unchanged.

2.8 The Media Descriptor Byte

In MS-DOS, the media descriptor byte is used to inform the DOS that a different type of media is present. The media descriptor byte can be any value between 0 and FFH. It does not have to be the same as the FAT ID byte. The FAT ID byte, which is the first byte of the FAT, was used in MS-DOS 1.00 to distinguish between different types of disk media, and may be used as well under 2.x and 3.x disk device drivers. However, FAT ID bytes have significance only for block device drivers where the non-FAT ID bit is not set (0).

Values of the media descriptor byte or the FAT ID byte have no significance to MS-DOS. They are passed to the device driver so that programs can determine the media type.

2.9 Format of a Media Descriptor Table

The MS-DOS file system uses a linked list of pointers (one for each cluster or allocation unit) called the File Allocation Table (FAT). Unused clusters are represented by zero and end-of-file by FFFH (or FFFFH on units with 16-bit FAT entries). No valid entry should ever point to a zero entry, but if one does, the first FAT entry (which would be pointed to by a zero entry) was reserved and set to end of chain. Eventually, several end of chain values were defined ([F]FF8-[F]FFFH), and these were used to distinguish different types of media.

A preferable technique is to write a complete media descriptor table in the boot sector and use it for media identification. To ensure backward compatibility for systems whose drivers do not set the non-FAT ID bit (including the IBM PC implementation), it is necessary also to write the FAT ID bytes during the format process.

To allow more flexibility for supporting many different disk formats in the future, it is recommended that the information relating to the BPB for a particular piece of media be kept in the boot sector. Figure 2.6 shows the format of such a boot sector.

```
+----------------------------------+
| 3 BYTE Near JUMP to boot code    |
```

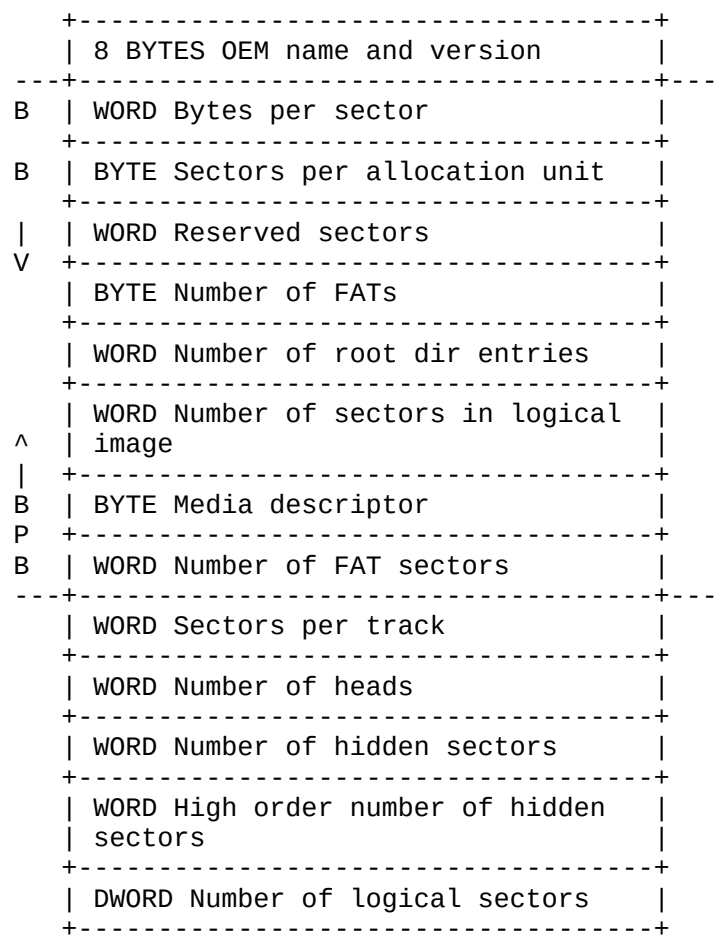


Figure 2.6 Format of a Boot Sector

Although MS-DOS does not use the five fields that follow the BPB, these fields may be used by a device driver to help it understand the media.

The "Sectors per track" and "Number of heads" fields are useful for supporting different media which may have the same logical layout, but a different physical layout (for example, 40-track, double-sided versus 80-track, single-sided). "Sectors per track" tells the device driver how the logical disk format is laid out on the physical disk.

The "Number of hidden sectors" and "High order number of hidden sectors" fields may be used to support drive-partitioning schemes.

The "Number of logical sectors" field is not currently used, but will tell the device driver how many sectors to reserve if the "Number of sectors in logical image" field is zero. (Note that this is intended for supporting devices that access more than 32 megabytes.)

The following procedure is recommended for media determination by NON FAT ID format drivers:

1. Read the boot sector of the drive into the one-sector scratch space pointed to by the DWORD transfer address.

2. Determine if the first byte of the boot sector is an E9H or EBIT (the first byte of a 3-byte NEAR or 2-byte SHORT jump) or an EBH (the first byte of a 2-byte jump followed by an NOP). If so, a BPB is located beginning at offset 3. Return a pointer to it.

3. If the boot sector does not have a BPB table, it is probably a disk

formatted under a 1.x version of MS-DOS and probably uses a FAT ID byte for determining media.

The driver may optionally attempt to read the first sector of the FAT into the one-sector scratch area and read the first byte to determine media type based upon whatever FAT ID bytes may have been used on disks that are expected to be read by this system. Return a pointer to a hard-coded BPB.

2.10 The CLOCK Device

MS-DOS assumes that some sort of clock is available in the system. This may either be a CMOS real-time clock or an interval timer that is initialized at boot time by the user. The CLOCK device defines and performs functions like any other character device, except that it is identified by a bit in the attribute word. The DOS uses this bit to identify it; consequently, the CLOCK device may take any name. The IBM implementation uses the name $CLOCK so as not to conflict with existing files named clock.

The CLOCK device is unique in that MS-DOS will read or write a 6-byte sequence that encodes the date and time. A write to this device will set the date and time; a read will get the date and time.

Figure 2.7 illustrates the binary time format used by the CLOCK device:

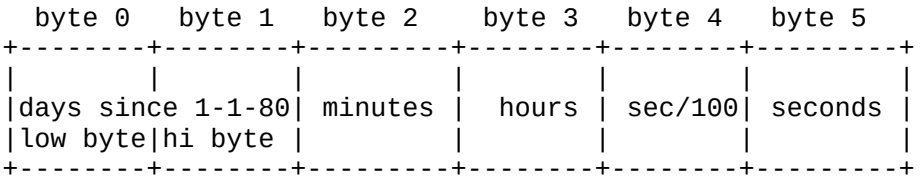


Figure 2.7 Format of a Clock Device

2.11 Anatomy of a Device Call

The following steps illustrate what happens when MS-DOS calls on a block device driver to perform a Write request:

1. MS-DOS writes a request packet in a reserved area of memory.

2. MS-DOS calls the strategy entry point of the block device driver.

3. The device driver saves the ES and BX registers (ES:BX points to the request packet) and does a FAR return.

4. MS-DOS calls the interrupt entry point.

5. The device driver retrieves the pointer to the request packet and reads the command code (offset 2) to determine that this is a Write request. The device driver converts the command code to an index into a dispatch table and control passes to the Write routine.

6. The device driver reads the unit code (offset 1) to determine which disk drive it is supposed to write to.

7. Since the command is a disk Write, the device driver must get the transfer address (offset 14), the sector count (offset 18), and the start sector (offset 20) in the request packet.

8. The device driver translates the first logical sector number into a track, head, and sector number.

9. The device driver writes the specified number of sectors, starting at the beginning sector on the drive defined by the unit code (the subunit defined by this device driver), and transfers data from the transfer address indicated in the request packet. Note that this may involve multiple Write commands to the disk controller.

10. After the transfer is complete, the device driver must report the status of the request to MS-DOS by setting the done bit in the status word (offset 3 in the request packet). It reports the number of sectors actually transferred in the sector count area of the request packet.

11. If an error occurs, the driver sets the done bit and the error bit in the status word and fills in the error code in the lower half of the status word. The number of sectors actually transferred must be written in the request header. It is not sufficient just to set the error bit of the status word.

12. The device driver does a FAR return to MS-DOS.

The device drivers should preserve the state of MS-DOS. This means that all registers (including flags) should be preserved. The direction flag and interrupt enable bits are critical. When the interrupt entry point in the device driver is called, MS-DOS has room for about 40 to 50 bytes on its internal stack. Your device driver should switch to a local stack if it uses extensive stack operations.

12.12 Two Sample Device Drivers

The following two examples illustrate a block device driver and a character device driver program. These examples are provided as guides for writing your own device drivers. However, since device drivers are hardware-dependent, your device drivers will differ.

Block Device Driver

```
;********************* A Block Device ******************

        Title   5.25-inch Disk Driver

;This driver is intended to drive up to four 5.25-inch
;drives hooked to a single disk controller. All standard
;IBM PC formats are supported.


FALSE   EQU     0
TRUE    EQU     NOT FALSE

;The I/O port address of the disk controller
DISK    EQU     0E0H
;DISK+0
;       1793    Command/Status
;DISK+1
;       1793    Track
;DISK+2
;       1793    Sector
;DISK+3
```

```
;       1793    Data
;DISK+4
;       Aux Command/Status
;DISK+5
;       Wait Sync

;Back side select bit
BACKBIT EQU     04H
;5 1/4" select bit
SMALBIT EQU     10H
;Double Density bit
DDBIT   EQU     08H

;Done bit in status register
DONEBIT EQU     01H

;Use table below to select head step speed.
;Step times for 5" drives
;are double that shown in the table.
;
;Step value    1771    1793
;
;    0          6ms     3ms
;    1          6ms     6ms
;    2         10ms    10ms
;    3         20ms    15ms
;
STPSPD  EQU     1

NUMERR  EQU     ERROUT-ERRIN

CR      EQU     0DH
LF      EQU     0AH

CODE    SEGMENT
ASSUME  CS:CODE,DS:NOTHING,ES:NOTHING,SS:NOTHING
;--------------------------------------------------
;
;       Device Header
;
DRVDEV  LABEL   WORD
        DW      -1,-1
        DW      0000     ;IBM format-compatible, Block
        DW      STRATEGY
        DW      DRV$IN
DRVMAX  DB      4

DRVTBL  LABEL   WORD
        DW      DRV$INIT
        DW      MEDIA$CHK
        DW      GET$BPB
        DW      CMDERR
        DW      DRV$READ
        DW      EXIT
        DW      EXIT
        DW      EXIT
        DW      DRV$WRIT
        DW      DRV$WRIT
        DW      EXIT
        DW      EXIT
        DW      EXIT

;-----------------------------------
;
```

```
;       Strategy

PTRSAV  DD      0

STRATP  PROC    FAR
STRATEGY:
        MOV     WORD PTR [PTRSAV],BX
        MOV     WORD PTR [PTRSAV+2],ES
        RET
STRATP  ENDP

;--------------------------------------
;
;       Main Entry


CMDLEN  =       0       ;Length of this command
UNIT    =       1       ;Subunit specified
CMDC    =       2       ;Command Code
STATUS  =       3       ;Status
MEDIA   =       13      ;Media Descriptor
TRANS   =       14      ;Transfer Address
COUNT   =       18      ;Count of blocks or characters
START   =       20      ;First block to transfer

DRV$IN:
        PUSH    SI
        PUSH    AX
        PUSH    CX
        PUSH    DX
        PUSH    DI
        PUSH    BP
        PUSH    DS
        PUSH    ES
        PUSH    BX

        LDS     BX,[PTRSAV]     ;Get pointer to I/O packet

        MOV     AL,BYTE PTR [BX].UNIT   ;AL = Unit Code
        MOV     AH,BYTE PTR [BX].MEDIA  ;AH = Media Descrip
        MOV     CX,WORD PTR [BX].COUNT  ;CX = Count
        MOV     DX,WORD PTR [BX].START  ;DX = Start Sector
        PUSH    AX
        MOV     AL,BYTE PTR [BX].CMDC   ;Command code
        CMP     AL,15
        JA      CMDERRP                 ;Bad command
        CBW
        SHL     AX,1                    ;2 times command =
                                        ;word table index
        MOV     SI,OFFSET DRVTBL
        ADD     SI,AX                   ;Index into table
        POP     AX                      ;Get back media
                                        ;and unit

        LES     DI,DWORD PTR [BX].TRANS ;ES:DI = Transfer
                                        ;Address

        PUSH    CS
        POP     DS

ASSUME  DS:CODE

        JMP     WORD PTR [SI]             ;GO DO COMMAND
```

```
;--------------------------------------------------------
;
;       EXIT - All Routines return through this path
;
ASSUME  DS:NOTHING
CMDERRP:
        POP     AX                      ;Clean stack
CMDERR:
        MOV     AL,3                    ;Unknown command error
        JMP     SHORT ERR$EXIT

ERR$CNT:LDS     BX,[PTRSAV]
        SUB     WORD PTR [BX].COUNT,CX ;# OF SUCCESS. I/Os

ERR$EXIT:
;AL has error code
        MOV     AH,10000001B            ;Mark error return
        JMP     SHORT ERR1

EXITP   PROC    FAR

EXIT:   MOV     AH,00000001B
ERR1:   LDS     BX,[PTRSAV]
        MOV     WORD PTR [BX].STATUS,AX
                                ;Mark Operation
CompleteE

        POP     BX
        POP     ES
        POP     DS
        POP     BP
        POP     DI
        POP     DX
        POP     CX
        POP     AX
        POP     SI
        RET                             ;Restore REGS and return
EXITP   ENDP

CURDRV  DB      -1

TRKTAB  DB      -1,-1,-1,-1

SECCNT  DW      0

DRVLIM  =       8       ;Number of sectors on device
SECLIM  =       13      ;Maximum Sector
HDLIM   =       15      ;Maximum Head

;WARNING - preserve order of drive and curhd!

DRIVE   DB      0       ;Physical Drive Code
CURHD   DB      0       ;Current Head
CURSEC  DB      0       ;Current Sector
CURTRK  DW      0       ;Current Track

;
MEDIA$CHK:              ;Always indicates Don't know
ASSUME  DS:CODE
        TEST    AH,00000100B       ;Test if Media Removable
        JZ      MEDIA$EXT
        XOR     DI,DI              ;Say I Don't know
MEDIA$EXT:
        LDS     BX,[PTRSAV]
```

```
        MOV     WORD PTR [BX].TRANS,DI
        JMP     EXIT

BUILD$BPB:
ASSUME  DS:CODE
        MOV     AH,BYTE PTR ES:[DI]       ;Get FAT ID Byte
        CALL    BUILDBP                   ;Translate
SETBPB: LDS     BX,[PTRSAV]
        MOV     [BX].MEDIA,AH
        MOV     [BX].COUNT,DI
        MOV     [BX].COUNT+2,CS
        JMP     EXIT

BUILDBP:
ASSUME  DS:NOTHING
;AH is media byte on entry
;DI points to correct BPB on return
        PUSH    AX
        PUSH    CX
        PUSH    DX
        PUSH    BX
        MOV     CL,AH       ;Save Media
        AND     CL,0F8H     ;Normalize
        CMP     CL,0F8H     ;Compare with Good Media Byte
        JZ      GOODID
        MOV     AH,0FEH     ;Default to 8-sector,
                            ;Single-sided
GOODID:
        MOV     AL,1        ;Set number of FAT sectors
        MOV     BX,64*256+8 ;Set Dir Entries and Sector Max
        MOV     CX,40*8     ;Set Size of Drive
        MOV     DX,01*256+1 ;Set Head Limit & Sec/All Unit
        MOV     DI,OFFSET DRVBPB
        TEST    AH,00000010B ;Test for 8 OR 9 Sectors
        JNZ     HAS8        ;NZ = has 8 sectors
        INC     AL          ;Inc Number of FAT sectors
        INC     BL          ;Inc Sector Max
        ADD     CX,40       ;Increase Size
HAS8:   TEST    AH,00000001B    ;Test for 1 or 2 Heads
        JZ      HAS1        ;Z = 1 Head
        ADD     CX,CX       ;Double Size of Disk
        MOV     BH,112      ;Increase # of Dir Entries
        INC     DH          ;Inc Sec/All Unit
        INC     DL          ;Inc Head Limit
HAS1:   MOV     BYTE PTR [DI].2,DH
        MOV     BYTE PTR [DI].6,BH
        MOV     WORD PTR [DI].8,CX
        MOV     BYTE PTR [DI].10,AH
        MOV     BYTE PTR [DI].11,AL
        MOV     BYTE PTR [DI].13,BL
        MOV     BYTE PTR [DI].15,DL
        POP     BX
        POP     DX
        POP     CX
        POP     AX
        RET

;--------------------------------------------------------
;
;       Disk I/O Handlers
;
;ENTRY:
;       AL = Drive Number (0-3)
;       AH = Media Descriptor
```

```
;       CX = Sector Count
;       DX = First Sector
;       DS = CS
;       ES:DI = Transfer Address
;EXIT:
;       IF Successful Carry Flag = 0
;         ELSE CF=1 AND AL contains (MS-DOS) Error Code,
          CX # sectors NOT transferred

DRV$READ:
ASSUME  DS:CODE
        JCXZ    DSKOK
        CALL    SETUP
        JC      DSK$IO
        CALL    DISKRD
        JMP     SHORT DSK$IO

DRV$WRIT:
ASSUME  DS:CODE
        JCXZ    DSKOK
        CALL    SETUP
        JC      DSK$IO
        CALL    DISKWRT
ASSUME  DS:NOTHING
DSK$IO: JNC     DSKOK
        JMP     ERR$CNT
DSKOK:  JMP     EXIT

SETUP:
ASSUME  DS:CODE
;Input same as above
;On output
; ES:DI = Trans addr
; DS:BX Points to BPB
; Carry set if error (AL is error code (MS-DOS))
; else
;       [DRIVE] = Drive number (0-3)
;       [SECCNT] = Sectors to transfer
;       [CURSEC] = Sector number of start of I/O
;       [CURHD]  = Head number of start of I/O   ;Set
;       [CURTRK] = Track # of start of I/O ;Seek performed
; All other registers destroyed

        XCHG   BX,DI              ;ES:BX = Transfer Address
        CALL   BUILDBP            ;DS:DI = PTR to B.P.B
        MOV    SI,CX
        ADD    SI,DX
        CMP    SI,WORD PTR [DI].DRVLIM
                                 ;Compare Against Drive Max
        JBE    INRANGE
        MOV    AL,8
        STC
        RET

INRANGE:
        MOV    [DRIVE],AL
        MOV    [SECCNT],CX     ;Save Sector Count
        XCHG   AX,DX           ;Set Up Logical Sector
                               ;For Divide
        XOR    DX,DX
        DIV    WORD PTR [DI].SECLIM ;Divide by Sec per Track
        INC    DL
        MOV    [CURSEC],DL          ;Save Current Sector
        MOV    CX,WORD PTR [DI].HDLIM ;Get Number of Heads
```

```
        XOR     DX,DX   ;Divide Tracks by Heads per Cylinder
        DIV     CX
        MOV     [CURHD],DL      ;Save Current Head
        MOV     [CURTRK],AX     ;Save Current Track
SEEK:
        PUSH    BX              ;Xaddr
        PUSH    DI              ;BPB pointer
        CALL    CHKNEW          ;Unload head if change drives
        CALL    DRIVESEL
        MOV     BL,[DRIVE]
        XOR     BH,BH           ;BX drive index
        ADD     BX,OFFSET TRKTAB        ;Get current track
        MOV     AX,[CURTRK]
        MOV     DL,AL          ;Save desired track
        XCHG    AL,DS:[BX]     ;Make desired track current
        OUT     DISK+1,AL      ;Tell Controller current track
        CMP     AL,DL          ;At correct track?
        JZ      SEEKRET        ;Done if yes
        MOV     BH,2           ;Seek retry count
        CMP     AL,-1          ;Position Known?
        JNZ     NOHOME         ;If not home head
TRYSK:
        CALL    HOME
        JC      SEEKERR
NOHOME:
        MOV     AL,DL
        OUT     DISK+3,AL       ;Desired track
        MOV     AL,1CH+STPSPD   ;Seek
        CALL    DCOM
        AND     AL,98H    ;Accept not rdy, seek, & CRC errors
        JZ      SEEKRET
        JS      SEEKERR         ;No retries if not ready
        DEC     BH
        JNZ     TRYSK
SEEKERR:
        MOV     BL,[DRIVE]
        XOR     BH,BH           ;BX drive index
        ADD     BX,OFFSET TRKTAB        ;Get current track
        MOV     BYTE PTR DS:[BX],-1     ;Make current track
                                        ;unknown
        CALL    GETERRCD
        MOV     CX,[SECCNT]     ;Nothing transferred
        POP     BX              ;BPB pointer
        POP     DI              ;Xaddr
        RET

SEEKRET:
        POP     BX              ;BPB pointer
        POP     DI              ;Xaddr
        CLC
        RET

;-----------------------------------------------
;
;       Read
;

DISKRD:
ASSUME  DS:CODE
        MOV     CX,[SECCNT]
RDLP:
        CALL    PRESET
        PUSH    BX
        MOV     BL,10              ;Retry count
```

```
        MOV     DX,DISK+3           ;Data port
RDAGN:
        MOV     AL,80H              ;Read command
        CLI                         ;Disable for 1793
        OUT     DISK,AL             ;Output read command
        MOV     BP,DI               ;Save address for retry
        JMP     SHORT RLOOPENTRY
RLOOP:
        STOSB
RLOOPENTRY:
        IN      AL,DISK+5           ;Wait for DRQ or INTRQ
        SHR     AL,1
        IN      AL,DX               ;Read data
        JNC     RLOOP
        STI                         ;Ints OK now
        CALL    GETSTAT
        AND     AL,9CH
        JZ      RDPOP               ;Ok
        MOV     DI,BP               ;Get back transfer
        DEC     BL
        JNZ     RDAGN
        CMP     AL,10H              ;Record not found?
        JNZ     GOT_CODE            ;No
        MOV     AL,1                ;Map it
GOT_CODE:
        CALL    GETERRCD
        POP     BX
        RET

RDPOP:
        POP     BX
        LOOP    RDLP
        CLC
        RET

;-----------------------------------------------
;
;       Write
;

DISKWRT:
ASSUME  DS:CODE
        MOV     CX,[SECCNT]
        MOV     SI,DI
        PUSH    ES
        POP     DS
ASSUME  DS:NOTHING
WRLP:
        CALL    PRESET
        PUSH    BX
        MOV     BL,10                   ;Retry count
        MOV     DX,DISK+3               ;Data port
WRAGN:
        MOV     AL,0A0H             ;Write command
        CLI                         ;Disable for 1793
        OUT     DISK,AL             ;Output write command
        MOV     BP,SI               ;Save address for retry
WRLOOP:
        IN      AL,DISK+5
        SHR     AL,1
        LODSB                       ;Get data
        OUT     DX,AL               ;Write data
        JNC     WRLOOP
        STI                         ;Ints OK now
```

```
        DEC     SI
        CALL    GETSTAT
        AND     AL,0FCH
        JZ      WRPOP               ;Ok
        MOV     SI,BP               ;Get back transfer
        DEC     BL
        JNZ     WRAGN
        CALL    GETERRCD
        POP     BX
        RET

WRPOP:
        POP     BX
        LOOP    WRLP
        CLC
        RET

PRESET:
ASSUME  DS:NOTHING
        MOV     AL,[CURSEC]
        CMP     AL,CS:[BX].SECLIM
        JBE     GOTSEC
        MOV     DH,[CURHD]
        INC     DH
        CMP     DH,CS:[BX].HDLIM
        JB      SETHEAD             ;Select new head
        CALL    STEP                ;Go on to next track
        XOR     DH,DH               ;Select head zero
SETHEAD:
        MOV     [CURHD],DH
        CALL    DRIVESEL
        MOV     AL,1                ;First sector
        MOV     [CURSEC],AL         ;Reset CURSEC
GOTSEC:
        OUT     DISK+2,AL      ;Tell controller which sector
        INC     [CURSEC]       ;We go on to next sector
        RET

STEP:
ASSUME  DS:NOTHING
        MOV     AL,58H+STPSPD  ;Step in w/ update, no verify
        CALL    DCOM
        PUSH    BX
        MOV     BL,[DRIVE]
        XOR     BH,BH           ;BX drive index
        ADD     BX,OFFSET TRKTAB        ;Get current track
        INC     BYTE PTR CS:[BX]        ;Next track
        POP     BX
        RET

HOME:
ASSUME  DS:NOTHING
        MOV     BL,3
TRYHOM:
        MOV     AL,0CH+STPSPD   ;Restore with verify
        CALL    DCOM
        AND     AL,98H
        JZ      RET3
        JS      HOMERR          ;No retries if not ready
        PUSH    AX              ;Save real error code
        MOV     AL,58H+STPSPD   ;Step in w/ update no verify
        CALL    DCOM
        DEC     BL
        POP     AX              ;Get back real error code
```

```
        JNZ     TRYHOM
HOMERR:
        STC
RET3:   RET

CHKNEW:
ASSUME  DS:NOTHING
        MOV     AL,[DRIVE]      ;Get disk drive number
        MOV     AH,AL
        XCHG    AL,[CURDRV]     ;Make new drive current.
        CMP     AL,AH           ;Changing drives?
        JZ      RET1            ;No
; If changing drives, unload head so the head load delay
;one-shot will fire again. Do it by seeking to the same
;track with the H bit reset.
;
        IN      AL,DISK+1       ;Get current track number
        OUT     DISK+3,AL       ;Make it the track to seek
        MOV     AL,10H          ;Seek and unload head

DCOM:
ASSUME  DS:NOTHING
        OUT     DISK,AL
        PUSH    AX
        AAM                     ;Delay 10 microseconds
        POP     AX
GETSTAT:
        IN      AL,DISK+4
        TEST    AL,DONEBIT
        JZ      GETSTAT
        IN      AL,DISK
RET1:   RET

DRIVESEL:
ASSUME  DS:NOTHING
;Select the drive based on current info
;Only AL altered
        MOV     AL,[DRIVE]
        OR      AL,SMALBIT + DDBIT      ;5 1/4" IBM PC disks
        CMP     [CURHD],0
        JZ      GOTHEAD
        OR      AL,BACKBIT      ;Select side 1
GOTHEAD:
        OUT     DISK+4,AL       ;Select drive and side
        RET

GETERRCD:
ASSUME  DS:NOTHING
        PUSH    CX
        PUSH    ES
        PUSH    DI
        PUSH    CS
        POP     ES              ;Make ES the local segment
        MOV     CS:[LSTERR],AL  ;Terminate list w/ error code
        MOV     CX,NUMERR       ;Number of error conditions
        MOV     DI,OFFSET ERRIN ;Point to error conditions
        RECRE   SCASB
        MOV     AL,NUMERR-1[DI] ;Get translation
        STC                     ;Flag error condition
        POP     DI
        POP     ES
        POP     CX
        RET                     ;and return
```

```
;*******************************************************
;       BPB for an IBM floppy disk, Various parameters are
;       patched by BUILDBP to reflect the type of Media
;       inserted
;       This is a 9-sector, single-side BPB
DRVBPB:
        DW      512          ;Physical sector size in bytes
        DB      1            ;Sectors/allocation unit
        DW      1            ;Reserved sectors for DOS
        DB      2            ;# of allocation tables
        DW      64           ;Number directory entries
        DW      9*40         ;Number 512-byte sectors
        DB      11111100B    ;Media descriptor
        DW      2            ;Number of FAT sectors
        DW      9            ;Sector limit
        DW      1            ;Head limit

INITAB  DW      DRVBPB               ;Up to four units
        DW      DRVBPB
        DW      DRVBPB
        DW      DRVBPB

ERRIN:  ;Disk errors returned from the controller
        DB      80H             ;No response
        DB      40H             ;Write protect
        DB      20H             ;Write Fault
        DB      10H             ;SEEK error
        DB      8               ;CRC error
        DB      1               ;Mapped from 10H
                                ;(record not found) on Read
LSTERR  DB      0               ;All other errors

ERROUT: ;Returned error codes corresponding to above
        DB      2               ;No response
        DB      0               ;Write Attempt
                                ;On Write-protected disk
        DB      0AH             ;Write fault
        DB      6               ;SEEK Failure
        DB      4               ;Bad CRC
        DB      8               ;Sector not found
        DB      12              ;General error

DRV$INIT:
;
; Determine number of physical drives by reading config.sys
;
ASSUME  DS:CODE
        PUSH    DS
        LDS     SI,[PTRSAV]
ASSUME  DS:NOTHING
        LDS     SI,DWORD PTR [SI.COUNT] ;DS:SI points to
                                        ;config.sys
SCAN_LOOP:
        CALL    SCAN_SWITCH
        MOV     AL,CL
        OR      AL,AL
        JZ      SCAN4
        CMP     AL,"s"
        JZ      SCAN4

WERROR: POP     DS
ASSUME  DS:CODE
        MOV     DX,OFFSET ERRMSG2
WERROR2: MOV    AH,9
```

```
        INT     21H
        XOR     AX,AX
        PUSH    AX                      ;No units
        JMP     SHORT ABORT

BADNDRV:
        POP     DS
        MOV     DX,OFFSET ERRMSG1
        JMP     WERROR2

SCAN4:
ASSUME  DS:NOTHING
;BX is number of floppies
        OR      BX,BX
        JZ      BADNDRV                 ;User error
        CMP     BX,4
        JA      BADNDRV                 ;User error
        POP     DS
ASSUME  DS:CODE
        PUSH    BX                      ;Save unit count
ABORT:  LDS     BX,[PTRSAV]
ASSUME  DS:NOTHING
        POP     AX
        MOV     BYTE PTR [BX].MEDIA,AL          ;Unit count
        MOV     [DRVMAX],AL
        MOV     WORD PTR [BX].TRANS,OFFSET DRV$INIT ;SET
                                                ;BREAK ADDRESS
        MOV     [BX].TRANS+2,CS
        MOV     WORD PTR [BX].COUNT,OFFSET INITAB
                                ;SET POINTER TO BPB ARRAY
        MOV     [BX].ceOUNT+2,CS
        JMP     EXIT
;
; Put switch in CL, value in BX
;
SCAN_SWITCH:
        XOR     BX,BX
        MOV     CX,BX
        LODSB
        CMP     AL,10
        JZ      NUMRET
        CMP     AL,"-"
        JZ      GOT_SWITCH
        CMP     AL,"/"
        JNZ     SCAN_SWITCH
GOT_SWITCH:
        CMP     BYTE PTR [SI+1],":"
        JNZ     TERROR
        LODSB
        OR      AL,20H          ; Convert to lowercase
        MOV     CL,AL           ; Get switch
        LODSB                   ; Skip ":"
;
;  Get number pointed to by [SI]
;
;  Wipes out AX,DX only     BX returns number
;
GETNUM1:LODSB
        SUB     AL,"0"
        JB      CHKRET
        CMP     AL,9
        JA      CHKRET
        CBW
        XCHG    AX,BX
```

```
        MOV     DX,10
        MUL     DX
        ADD     BX,AX
        JMP     GETNUM1

CHKRET: ADD     AL,"0"
        CMP     AL," "
        JBE     NUMRET
        CMP     AL,"-"
        JZ      NUMRET
        CMP     AL,"/"
        JZ      NUMRET
TERROR:
        POP     DS              ; Get rid of return address
        JMP     WERROR
NUMRET: DEC     SI
        RET

ERRMSG1 DB      "SMLDRV: Bad number of drives",13,10,"$"
ERRMSG2 DB      "SMLDRV: Invalid parameter",13,10,"$"
CODE    ENDS
        END
```

Character Device Driver

The following program illustrates a character device driver program.

```
;******************** A Character Device *******************

Title   VT52 Console for 2.0    (IBM)

;:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
;
;       IBM Addresses for I/O
;
;:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::

        CR=13               ;Carriage-Return
        BACKSP=8            ;BACKSPACE
        ESC=1BH
        BRKADR=6CH          ;006C  Break vector address
        ASNMAX=200          ;Size of key assignment buffer

CODE    SEGMENT BYTE

   ASSUME CS:CODE,DS:NOTHING,ES:NOTHING
;-----------------------------------------------------------
;
;       C O N - Console Device Driver
;
CONDEV:                             ;Header for device "CON"
        DW      -1,-1
        DW      1000000000010011B  ;CON IN AND CON OUT
        DW      STRATEGY
        DW      ENTRY
        DB      'CON     '

;-----------------------------------------------------------
;
;       Command JUMP Tables
CONTBL:
        DW      CON$INIT
```

```
        DW      EXIT
        DW      EXIT
        DW      CMDERR
        DW      CON$READ
        DW      CON$RDND
        DW      EXIT
        DW      CON$FLSH
        DW      CON$WRIT
        DW      CON$WRIT
        DW      EXIT
        DW      EXIT

CMDTABL DB      'A'
        DW      CUU             ;cursor up
        DB      'B'
        DW      CUD             ;cursor down
        DB      'C'
        DW      CUF             ;cursor forward
        DB      'D'
        DW      CUB             ;cursor back
        DB      'H'
        DW      CUH             ;cursor position
        DB      'J'
        DW      ED              ;erase display
        DB      'K'
        DW      EL              ;erase line
        DB      'Y'
        DW      CUP             ;cursor position
        DB      'j'
        DW      PSCP            ;save cursor position
        DB      'k'
        DW      PRCP            ;restore cursor position
        DB      'y'
        DW      RM              ;reset mode
        DB      'x'
        DW      SM              ;set mode
        DB      00

PAGE
;-----------------------------------------------------
;
;       Device entry point
;
CMDLEN  =       0       ;Length of this command
UNIT    =       1       ;Subunit Specified
CMD     =       2       ;Command Code
STATUS  =       3       ;Status
MEDIA   =       13      ;Media Descriptor
TRANS   =       14      ;Transfer Address
COUNT   =       18      ;Count of blocks or characters
START   =       20      ;First block to transfer

PTRSAV  DD      0

STRATP  PROC    FAR

STRATEGY:
        MOV     WORD PTR CS:[PTRSAV],BX
        MOV     WORD PTR CS:[PTRSAV+2],ES
        RET

STRATP  ENDP

ENTRY:
```

```
        PUSH    SI
        PUSH    AX
        PUSH    CX
        PUSH    DX
        PUSH    DI
        PUSH    BP
        PUSH    DS
        PUSH    ES
        PUSH    BX

        LDS     BX,CS:[PTRSAV]  ;GET POINTER TO I/O PACKET

        MOV     CX,WORD PTR DS:[BX].COUNT    ;CX = COUNT

        MOV     AL,BYTE PTR DS:[BX].CMD
        CBW
        MOV     SI,OFFSET CONTBL
        ADD     SI,AX
        ADD     SI,AX
        CMP     AL,11
        JA      CMDERR

        LES     DI,DWORD PTR DS:[BX].TRANS

        PUSH    CS
        POP     DS

        ASSUME  DS:CODE

        JMP     WORD PTR [SI]              ;GO DO COMMAND

PAGE
;=====================================================
;=
;=      Subroutines Shared by Multiple Devices
;=
;=====================================================
;-----------------------------------------------------
;
;       EXIT - All routines return through this path
;
BUS$EXIT:                                  ;Device Busy Exit
        MOV     AH,00000011B
        JMP     SHORT ERR1

CMDERR:
        MOV     AL,3                ;Unknown command error

ERR$EXIT:
        MOV     AH,10000001B            ;Mark error Return
        JMP     SHORT ERR1

EXITP   PROC    FAR

EXIT:   MOV     AH,00000001B
ERR1:   LDS     BX,CS:[PTRSAV]
        MOV     WORD PTR [BX].STATUS,AX ;Mark
                                        ;Operation Complete

        POP     BX
        POP     ES
        POP     DS
        POP     BP
        POP     DI
```

```
        POP     DX
        POP     CX
        POP     AX
        POP     SI
        RET                         ;Restore REGS and Return
EXITP   ENDP
;-----------------------------------------------
;
;       BREAK Key Handling
;
BREAK:
        MOV     CS:ALTAH,3          ;Indicate BREAK key Set
INTRET: IRET

PAGE
;
;       WARNING - Variables are very order dependent,
                  so be careful when adding new ones!
;
WRAP    DB      0               ; 0 = WRAP, 1 = NO WRAP
STATE   DW      S1
MODE    DB      3
MAXCOL  DB      79
COL     DB      0
ROW     DB      0
SAVCR   DW      0
ALTAH   DB      0               ;Special key handling

;-------------------------------------------------------
;
;    CHROUT - Write out Char in AL using current attribute
;
ATTRW   LABEL   WORD
ATTR    DB      00000111B       ;Character Attribute
BPAGE   DB      0               ;Base Page
base    dw      0b800h

chrout: cmp     al,13
        jnz     trylf
        mov     [col],0
        jmp     short setit

trylf:  cmp     al,10
        jz      lf
        cmp     al,7
        jnz     tryback
torom:
        mov     bx,[attrw]
        and     bl,7
        mov     ah,14
        int     10h
ret5:   ret

tryback:
        cmp     al,8
        jnz     outchr
        cmp     [col],0
        jz      ret5
        dec     [col]
        jmp     short setit

outchr:
        mov     bx,[attrw]
        mov     cx,1
```

```
        mov     ah,9
        int     10h
        inc     [col]
        mov     al,[col]
        cmp     al,[maxcol]
        jbe     setit
        cmp     [wrap],0
        jz      outchr1
        dec     [col]
        ret
outchr1:
        mov     [col],0
lf:     inc     [row]
        cmp     [row],24
        jb      setit
        mov     [row],23
        call    scroll

setit:  mov     dh,row
        mov     dl,col
        xor     bh,bh
        mov     ah,2
        int     10h
        ret

scroll: call    getmod
        cmp     al,2
        jz      myscroll
        cmp     al,3
        jz      myscroll
        mov     al,10
        jmp     torom
myscroll:
        mov     bh,[attr]
        mov     bl,' '
        mov     bp,80
        mov     ax,[base]
        mov     es,ax
        mov     ds,ax
        xor     di,di
        mov     si,160
        mov     cx,23*80
        cld
        cmp     ax,0b800h
        jz      colorcard

        rep     movsw
        mov     ax,bx
        mov     cx,bp
        rep     stosw
sret:   push    cs
        pop     ds
        ret

colorcard:
        mov     dx,3dah
wait2:  in      al,dx
        test    al,8
        jz      wait2
        mov     al,25h
        mov     dx,3d8h
        out     dx,al           ;turn off video
        rep     movsw
        mov     ax,bx
```

```
        mov     cx,bp
        rep     stosw
        mov     al,29h
        mov     dx,3d8h
        out     dx,al           ;turn on video
        jmp     sret

GETMOD: MOV     AH,15
        INT     16              ;get column information
        MOV     BPAGE,BH
        DEC     AH
        MOV     WORD PTR MODE,AX
        RET
;--------------------------------------------------
;
;       Console Read Routine
;
CON$READ:
        JCXZ    CON$EXIT
CON$LOOP:
        PUSH    CX              ;Save Count
        CALL    CHRIN           ;Get Char in AL
        POP     CX
        STOSB                   ;Store Char at ES:DI
        LOOP    CON$LOOP
CON$EXIT:
        JMP     EXIT
;----------------------------------------------------------
;
;       Input Single Char into AL
;
CHRIN:  XOR     AX,AX
        XCHG    AL,ALTAH     ;Get Character & Zero ALTAH
        OR      AL,AL
        JNZ     KEYRET

INAGN:  XOR     AH,AH
        INT     22
ALT10:
        OR      AX,AX       ;Check for non-key after BREAK
        JZ      INAGN
        OR      AL,AL       ;Special case?
        JNZ     KEYRET
        MOV     ALTAH,AH        ;Store special key
KEYRET: RET
;-----------------------------------------------------------
;
;       Keyboard Non-descructive Read, No Wait
;
CON$RDND:
        MOV     AL,[ALTAH]
        OR      AL,AL
        JNZ     RDEXIT

RD1:    MOV     AH,1
        INT     22
        JZ      CONBUS
        OR      AX,AX
        JNZ     RDEXIT
        MOV     AH,0
        INT     22
        JMP     CON$RDND

RDEXIT: LDS     BX,[PTRSAV]
```

```
        MOV     [BX].MEDIA,AL
EXVEC:  JMP     EXIT
CONBUS: JMP     BUS$EXIT
;--------------------------------------------------------
;
;       Keyboard Flush Routine
;
CON$FLSH:
        MOV     [ALTAH],0         ;Clear out holding buffer

        PUSH    DS
        XOR     BP,BP
        MOV     DS,BP                   ;Select segment 0
        MOV     DS:BYTE PTR 41AH,1EH    ;Reset KB queue head
                                        ;pointer
        MOV     DS:BYTE PTR 41CH,1EH    ;Reset tail pointer
        POP     DS
        JMP     EXVEC
;--------------------------------------------------------
;
;       Console Write Routine
;
CON$WRIT:
        JCXZ    EXVEC
        PUSH    CX
        MOV     AH,3            ;Set current cursor position
        XOR     BX,BX
        INT     16
        MOV     WORD PTR [COL],DX
        POP     CX

CON$LP: MOV     AL,ES:[DI]      ;Get Char
        INC     DI
        CALL    OUTC            ;Output Char
        LOOP    CON$LP          ;Repeat until all through
        JMP     EXVEC

COUT:   STI
        PUSH    DS
        PUSH    CS
        POP     DS
        CALL    OUTC
        POP     DS
        IRET

OUTC:   PUSH    AX
        PUSH    CX
        PUSH    DX
        PUSH    SI
        PUSH    DI
        PUSH    ES
        PUSH    BP
        CALL    VIDEO
        POP     BP
        POP     ES
        POP     DI
        POP     SI
        POP     DX
        POP     CX
        POP     AX
        RET

;--------------------------------------------------------
;
```

```
;       Output Single Char in AL to Video Device
;
VIDEO:  MOV     SI,OFFSET STATE
        JMP     [SI]

S1:     CMP     AL,ESC                  ;Escape sequence?
        JNZ     S1B
        MOV     WORD PTR [SI],OFFSET S2
        RET

S1B:    CALL    CHROUT
S1A:    MOV     WORD PTR [STATE],OFFSET S1
        RET

S2:     PUSH    AX
        CALL    GETMOD
        POP     AX
        MOV     BX,OFFSET CMDTABL-3
S7A:    ADD     BX,3
        CMP     BYTE PTR [BX],0
        JZ      S1A
        CMP     BYTE PTR [BX],AL
        JNZ     S7A
        JMP     WORD PTR [BX+1]

MOVCUR: CMP     BYTE PTR [BX],AH
        JZ      SETCUR
        ADD     BYTE PTR [BX],AL
SETCUR: MOV     DX,WORD PTR COL
        XOR     BX,BX
        MOV     AH,2
        INT     16
        JMP     S1A

CUP:    MOV     WORD PTR [SI],OFFSET CUP1
        RET
CUP1:   SUB     AL,32
        MOV     BYTE PTR [ROW],AL
        MOV     WORD PTR [SI],OFFSET CUP2
        RET
CUP2:   SUB     AL,32
        MOV     BYTE PTR [COL],AL
        JMP     SETCUR

SM:     MOV     WORD PTR [SI],OFFSET S1A
        RET

CUH:    MOV     WORD PTR COL,0
        JMP     SETCUR

CUF:    MOV     AH,MAXCOL
        MOV     AL,1
CUF1:   MOV     BX,OFFSET COL
        JMP     MOVCUR

CUB:    MOV     AX,00FFH
        JMP     CUF1

CUU:    MOV     AX,00FFH
CUU1:   MOV     BX,OFFSET ROW
        JMP     MOVCUR

CUD:    MOV     AX,23*256+1
        JMP     CUU1
```

```
PSCP:   MOV     AX,WORD PTR COL
        MOV     SAVCR,AX
        JMP     SETCUR

PRCP:   MOV     AX,SAVCR
        MOV     WORD PTR COL,AX
        JMP     SETCUR

ED:     CMP     BYTE PTR [ROW],24
        JAE     EL1

        MOV     CX,WORD PTR COL
        MOV     DH,24
        JMP     ERASE

EL1:    MOV     BYTE PTR [COL],0
EL:     MOV     CX,WORD PTR [COL]
EL2:    MOV     DH,CH
ERASE:  MOV     DL,MAXCOL
        MOV     BH,ATTR
        MOV     AX,0600H
        INT     16
ED3:    JMP     SETCUR


RM:     MOV     WORD PTR [SI],OFFSET RM1
        RET
RM1:    XOR     CX,CX
        MOV     CH,24
        JMP     EL2

CON$INIT:
        int     11h
        and     al,00110000b
        cmp     al,00110000b
        jnz     iscolor
        mov     [base],0b000h           ;look for bw card
iscolor:
        cmp     al,00010000b            ;look for 40 col mode
        ja      setbrk
        mov     [mode],0
        mov     [maxcol],39

setbrk:
        XOR     BX,BX
        MOV     DS,BX
        MOV     BX,BRKADR
        MOV     WORD PTR [BX],OFFSET BREAK
        MOV     WORD PTR [BX+2],CS

        MOV     BX,29H*4
        MOV     WORD PTR [BX],OFFSET COUT
        MOV     WORD PTR [BX+2],CS

        LDS     BX,CS:[PTRSAV]
        MOV     WORD PTR [BX].TRANS,OFFSET CON$INIT
                        ;SET BREAK ADDRESS
        MOV     [BX].TRANS+2,CS
        JMP     EXIT

CODE    ENDS
        END
```

Chapter 3 MS-DOS Technical Information

.....

3.1 Introduction

3.2 MS-DOS Initialization

3.3 The Command Processor

3.4 MS-DOS Disk Allocation

3.5 MS-DOS Disk Directory

3.6 File Allocation Table (FAT)

      3.6.1 How to Use the FAT (12-Bit FAT Entries)

      3.6.2 How to Use the FAT (16-Bit FAT Entries)

3.7 MS-DOS Standard Disk Formats

3.1 Introduction

This chapter describes how MS-DOS initializes and how it allocates disk space for the root directory, the File Allocation Tables (FAT), and the data area. For programmers writing installable device drivers, this chapter explains MS-DOS disk directory entries and File Allocation Tables. At the end of the chapter, Tables 3.1 and 3.2 describe MS-DOS standard formats for floppy disks.

3.2 MS-DOS Initialization

MS-DOS initialization consists of several steps. When you reset your computer or turn on its power, the ROM (Read Only Memory) BIOS is invoked and performs hardware checks and initialization. The ROM BIOS then examines drive A for the boot sector. If it locates a boot sector, the ROM BIOS reads it into low memory and gives it control. If it doesn't find the boot sector, the ROM BIOS then looks in the active partition of the hard disk. If it still doesn't find the boot sector, the ROM BIOS then invokes ROM BASIC.

On a removable disk (3.5-inch, 5.25-inch, or 8-inch disk), the boot sector sector is always located on track 0, sector 1, side 0 of the disk. On a hard disk, the boot sector begins on the first sector of the MS-DOS partition. The hard disk boot sector also includes a partition table. This table identifies the active MS-DOS partition and any other partitions, such as an extended MS-DOS partition, on the hard disk. Note that extended MS-DOS partitions are not bootable.

The boot sector then reads the following files, in the order listed:

io.sys
msdos.sys

.....
Note

Versions of MS-DOS prior to 3.3 required the io.sys file to be contiguous. This is no longer a requirement.
.....

Next, the system initialization routine SYSINIT loads all of the resident device drivers. Then, it searches for a config.sys file on the boot disk. SYSINIT allocates memory for buffers and files, based on settings in the config.sys file, or system default settings. If the config.sys file specifies any installable device drivers, these are installed next.

Finally, SYSINIT executes the MS-DOS command processor, command.com.

3.3 The Command Processor

The command processor command.com consists of three parts:

- A resident part resides in memory immediately following msdos.sys and its data area. This part contains routines to process Interrupts 22H (Terminate Process Exit Address), 23H (CONTROL-C Exit Address), and 24H (Critical-Error-Handler Address), as well as a routine to reload the transient part, if needed. All standard MS-DOS error handling is done within this part of command.com. This includes displaying error messages and processing the Abort, Retry, Fail, or Ignore messages.

- An initialization part follows the resident part. During startup, the initialization part is given control; it contains the processor setup routine in the autoexec.bat file. The initialization part determines the segment address at which programs can be loaded, and because it is no longer needed, is overlaid by the first program that command.com loads.

- A transient part is loaded at the high end of memory. This part contains all the internal command processors and the batch file processor.

  The transient part of the command processor produces the system prompt (A>, for example), reads commands from the keyboard (or from batch files), and causes them to be executed. For external commands, the transient part builds a command line and issues Function 4BH (Load and Execute Program) to load and transfer control to the program.

3.4 MS-DOS Disk Allocation

The area on a disk partitioned for use by MS-DOS is formatted as follows:

1. Reserved area--variable size

2. First copy of File Allocation Table--variable size

3. Additional copies of File Allocation Table--variable size (optional)

4. Root directory--variable size

5. File data area

Space for a file in the data area is not preallocated. The space is allocated one cluster at a time. A cluster consists of one or more

consecutive sectors (the number of sectors in a cluster must be a power of 2); the cluster size is determined at format time. All the clusters for a file are "chained" together in the File Allocation Table, discussed in greater detail in Section 3.5, "File Allocation Table (FAT)." MS-DOS normally keeps a second copy of the FAT for consistency, except in the case of reliable storage such as a virtual RAM disk. Should the disk develop a bad sector in the middle of the first FAT, MS-DOS can use the second. This avoids loss of data due to an unreadable FAT.

3.5 MS-DOS Disk Directory

The format utility builds the root directory for all disks. This directory's location on the disk and the maximum number of entries are dependent on the media. Specifications for standard removable-disk formats are outlined later in this chapter. Note, however, that MS-DOS regards directories, other than the root directory, as files, so there is no limit to the number of files that the subdirectories under the root directory may contain.

All directory entries are 32 bytes in length and are in the following format (note that byte offsets are in hexadecimal):

Byte	Function
0-7	Filename. Eight characters, left-aligned and padded, if necessary, with blanks. The first byte of this field indicates the file status as follows: Byte Status 00H The directory entry has never been used. This is used to limit the length of directory searches, for performance reasons. 05H The first character of the filename contains an E5H character.
Byte	Function
#	05H The first character of the filename contains an E5H character. 2EH The entry is for a directory. If the second byte is also 2EH, the cluster field contains the cluster number of this directory's parent directory (0000H if the parent directory is the root directory). Otherwise, bytes 01H through 0AH are all spaces, and the cluster field contains the cluster number of this directory. E5H The file was used, but it has since been erased. Any other character is the first character of a filename.
8-0A	Filename extension.
0B	File attribute. The attribute byte is mapped as follows (values are in hexadecimal): Byte Contents
Byte	Function
#	01H File is marked read-only. An attempt to open the file for writing using Function 3DH (Open Handle) results in an error code being returned. This value can be used in programs along with the other attributes in this list. Attempts to delete

the file with Function 13H (Delete File) or Function 41H (Delete Directory Entry) will also fail.

02H Hidden file. The file is excluded from normal directory searches.

04H System file. The file is excluded from normal directory searches.

08H The entry contains the volume label in the first 11 bytes. The entry contains no other usable information (except date and time of creation), and may exist only in the root directory.

10H The entry defines a subdirectory, and is excluded from

Byte Function

10H The entry defines a subdirectory, and is excluded from normal directory searches.

20H Archive bit. The bit is set to "on" whenever the file has been written to and closed.

Note: The system files (io.sys and msdos.sys) are marked as read-only, hidden, and system files. Files can be marked hidden when they are created. Also, you may change the read-only, hidden, system, and archive attributes through Function 43H (Get/Set File Attributes).

0C-15 Reserved.

16-17 Time the file was created or last updated. The hour, minutes, and seconds are mapped into two bytes as follows (bit 7 on the left, 0 on the right):

Offset 17H
| H | H | H | H | H | M | M | M |

Byte Function

| H | H | H | H | H | M | M | M |

Offset 16H
| M | M | M | S | S | S | S | S |

where:

H is the binary number of hours (0-23).
M is the binary number of minutes (0-59).
S is the binary number of two-second increments.

18-19 Date the file was created or last updated. The year, month, and day are mapped into two bytes as follows:

Offset 19H
| Y | Y | Y | Y | Y | Y | Y | M |

Offset 18H
| M | M | M | D | D | D | D | D |

Byte Function

#

where:

Y is the year, 0-119 (1980-2099).
M is the month (1-12).
D is the day of the month (1-31).

1A-1B Starting cluster; the number of the first cluster in the file.

·· Note that the first cluster for data space on all disks is cluster 002.

·· The cluster number is stored with the least significant byte first.

·· For details about converting cluster numbers to logical sector numbers, see Sections 3.6.1 and 3.6.2.

1C-1F File size in bytes. The first word of this four-byte field is the low-order part of the size.

Byte Function

is the low-order part of the size.

3.6 File Allocation Table (FAT)

This section explains how MS-DOS allocates disk space in the data area for a file by using the File Allocation Table to convert the clusters of a file to logical sector numbers. The device driver is then responsible for locating the logical sector on the disk. Programs should use the MS-DOS file management function calls for accessing files. Programs that access the FAT are not guaranteed to be upwardly-compatible with future releases of MS-DOS. The following information is useful to system programmers who wish to write installable device drivers.

The File Allocation Table is an array of 12-bit entries (1.5 bytes) for each cluster on the disk. For disks containing more than 4085 clusters, a 16-bit FAT entry is used.

The first two FAT entries are reserved; however, the device driver may use the first byte as a FAT ID byte for determining media. For hard disks, the value of this byte is F8H. See Tables 3.1 and 3.2 for the media byte descriptors used for 8-inch, 5.25-inch, and 3.5-inch disks.

The third FAT entry, which starts at byte offset 4, begins the mapping of the data area (cluster 002). The operating system does not always sequentially write (to the disk) files in the data area. Instead, the system allocates the data area one cluster at a time, skipping over clusters it has already allocated. The first free cluster following the last cluster allocated for that file is the next cluster allocated, regardless of its physical location on the disk. This permits the most efficient use of disk space, since if you erase old files, you can free clusters, which the operating system can then allocate for new files.

Each FAT entry contains three or four hexadecimal characters, depending on whether it is a 12-bit or 16-bit entry:

Entry	Contents
(0)000	If the cluster is unused and available.
(F)FF7	The cluster has a bad sector in it if it is not part of any cluster chain. MS-DOS will not allocate such a cluster. So for its report, the chkdsk command counts the number of bad clusters, which are not part of any allocation chain.
(F)FF8-FFF	The last cluster of a file.
(X)XXX	Any other characters that are the cluster number of the next

cluster in the file. The number of the first cluster in the file is in the file's directory entry.

The File Allocation Table always begins on the first sector after the reserved sectors. If the FAT is larger than one sector, the sectors are contiguous. The operating system usually writes two copies of the FAT to preserve data integrity. MS-DOS reads the FAT into one of its buffers, whenever needed (open, read, write, etc.). The operating system also gives this buffer a high priority to keep it in memory as long as possible.

3.6.1 How to Use the FAT (12-Bit FAT Entries)

To get the starting cluster of a file, examine its directory entry (in the FAT). Then, to locate each subsequent cluster of the file, follow these steps:

1. Multiply the cluster number just used by 1.5 (each FAT entry is 1.5 bytes in length).

2. The whole part of the product is an offset into the FAT, pointing to the entry that maps the cluster just used. That entry contains the cluster number of the next cluster of the file.

3. Use a MOV instruction to move the word at the calculated FAT offset into a register.

4. If the last cluster used was an even number, keep the low-order 12 bits of the register by using the AND operator with 0FFFH and the register. If the last cluster used was an odd number, keep the high-order 12 bits by using the SHR instruction to shift the register right four bits.

5. If the resultant 12 bits are 0FF8H-0FFFH, the file contains no more clusters. Otherwise, the 12 bits contain the number of the next cluster in the file.

To convert the cluster to a logical sector number (relative sector, such as that used by Interrupts 25H and 26H (Absolute Disk Read/Write) and by debug), follow these steps:

1. Subtract two from the cluster number.

2. Multiply the result by the number of sectors per cluster.

3. To this result, add the logical sector number of the beginning of the data area.

3.6.2 How to Use the FAT (16-Bit FAT Entries)

To get the starting cluster of a file, examine its directory entry (in the FAT). Then, to find the next file cluster, follow these steps:

1. Multiply the cluster number last used by 2 (each FAT entry is 2 bytes).

2. Use a MOV WORD instruction to move the word at the calculated FAT offset into a register.

3. If the resultant 16 bits are 0FFF8-0FFFH, no more clusters are in the file. Otherwise, the 16 bits contain the number of the next cluster in the file.

3.7 MS-DOS Standard Disk Formats

MS-DOS arranges data clusters on a disk to minimize head movement. MS-DOS then allocates all the space on one track (or cylinder) before moving to the next. It uses the sequential sectors on the lowest-numbered head, then all the sectors on the next head, and so on, until it has used all the sectors on all the heads of the track.

The size of the MS-DOS partition on a hard disk determines the size of the FAT and root directory. Likewise, the type of floppy disk (tracks per side, sectors per track, etc.) determines how MS-DOS uses the disk. The removable disk formats listed in Tables 3.1 and 3.2 are standard and should be readable in the appropriate standard drive.

Table 3.1
MS-DOS Standard Removable-Disk Formats

Disk Size in inches	5.25				8		
WORD no. heads	1	1	2	2	1	2	1
Tracks/side	40	40	40	40	77	77	77
WORD sectors/track	8	9	8	9	26	26	8
WORD bytes/sector	512	512	512	512	128	128	024
BYTE sectors/cluster	1	1	2	2	4	4	1
WORD reserved sectors	1	1	1	1	1	4	1
Byte no. FATs	2	2	2	2	2	2	2
WORD root directory entries	64	64	112	112	68	68	192
WORD no. sectors	320	360	640	720	2002	2002	616
BYTE media descriptor	FE	FC	FF	FD	FE#1	FD	FE#1
WORD sectors/FAT	1	2	1	2	6	6	2
Disk Size in inches		5.25				8	
#WORD sectors/FAT	1	2	1	2	6	6	2
WORD no. hidden sectors	0	0	0	0	0	0	0

Table 3.2
MS-DOS Standard Removable Disk Formats (High-Density)

Disk Size in inches	3.5 or 5.25				3.5	5.25
WORD no. heads	1	2	2	2	2	2
Tracks/side	80	80	80	80	80	80
WORD sectors/track	8	9	8	9	18	15
WORD bytes/sector	512	512	512	512	512	512
BYTE sectors/cluster	2	2	2	2	1	1
WORD reserved sectors	1	1	1	1	1	1
BYTE no. FATs	2	2	2	2	2	2
WORD root dir entries	112	112	112	112	224	224
WORD no. sectors	640	720	1280	1440	2880	2400
BYTE media descriptor#1	FA	FC	FB	F9	F0	F9
WORD sectors/FAT	1	2	2	3	9	7
Disk Size in inches		3.5 or 5.25			3.5	5.25
#WORD sectors/FAT	1	2	2	3	9	7
WORD no. hidden sectors	0	0	0	0	0	0

Chapter 4 MS-DOS Control Blocks and Work Areas

.....

4.1 Introduction

4.2 Typical Contents of an MS-DOS Memory Map

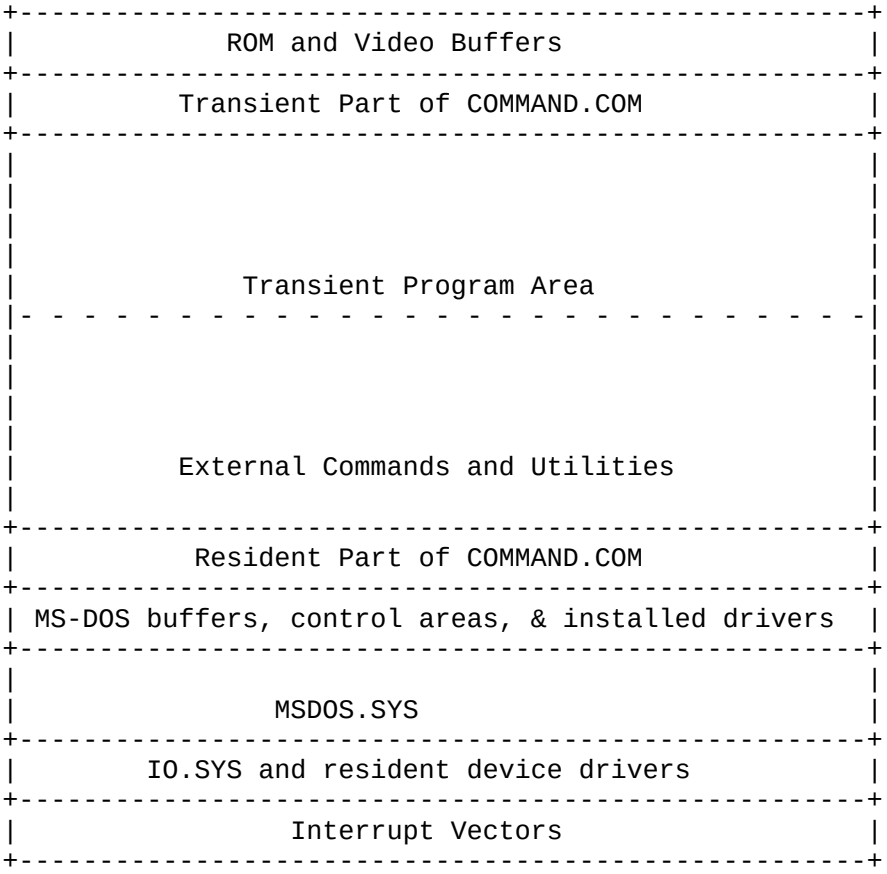
4.3 MS-DOS Program Segment

4.1 Introduction

This chapter describes a typical MS-DOS memory map and explains how a program is loaded into memory. It also describes the structure of an MS-DOS program segment and the contents of register segments for .exe and .com program files.

4.2 Typical Contents of an MS-DOS Memory Map

A typical MS-DOS memory map contains the following information:



During system initialization, MS-DOS loads the io.sys and msdos.sys files into low memory (Note that in MS-DOS 3.3, these files are not required to be written contiguously to the disk). The io.sys system file is the MS-DOS interface to hardware. The msdos.sys system file includes MS-DOS interrupt handlers, service routines (Interrupt 21H functions).

Next, the system initialization routine loads the resident and installable

device drivers. Above the installable device drivers, MS-DOS writes the resident part of command.com. This part includes interrupt handlers for Interrupts 22H (Terminate Process Exit Address), 23H (CONTROL-C Handler Address), 24H (Critical-Error-Handler Address) and code to reload the transient part. The transient part of command.com is reloaded into high memory. It includes the command interpreter, the internal MS-DOS commands, and the batch processor.

External command and utility (.com and .exe) files are loaded into the transient program area. MS-DOS also allocates 256 bytes for user stack used with .com files. User memory is allocated from the lowest end of available memory that fulfills the allocation request.

4.3 MS-DOS Program Segment

When you type an external command or execute a program through Function 4BH (Load and Execute Program, also called EXEC), MS-DOS determines the lowest available free memory address to use as the start of the program. The memory starting at this address is called the Program Segment.

The EXEC system call sets up the first 256 bytes of the Program Segment for the program being loaded into memory. The program is then loaded following this block. An .exe file with minalloc and maxalloc both set to zero is loaded as high as possible.

At offset 0 within the Program Segment, MS-DOS builds the Program Segment Prefix control block. The program returns from EXEC by one of five methods:

- By issuing an Interrupt 21H with AH=4CH
- By issuing an Interrupt 21H with AH=31H (Keep Process)
- By a long jump to offset 0 in the Program Segment Prefix
- By issuing an Interrupt 20H with CS:0 pointing at the PSP
- By issuing an Interrupt 21H with register AH=0 and with CS:0 pointing at the PSP

.....
Note
The first two methods are preferred for functionality, compatibility, and efficiency in future versions of MS-DOS.
.....

All five methods transfer control to the program that issued the EXEC call. The first two methods return a completion code. They also restore the addresses of Interrupts 22H, 23H, and 24H (Terminate Process Exit Address, CONTROL-C Handler Address, and Critical-Error-Handler Address) from the values saved in the Program Segment Prefix of the terminating program. Control then passes to the terminate address.

If a program returns to command.com, control transfers to the resident portion. If the program is a batch file (in process), it continues. Otherwise, command.com performs a checksum on the transient part, reloads it if necessary, issues the system prompt, and waits for you to type another command.

When a program receives control, the following conditions are in effect:

For all programs:

·· The segment address of the passed environment is at offset 2CH in the Program Segment Prefix.

·· The environment is a series of ASCII strings (totaling less than 32K) in the form:

NAME=parameter

·· A byte of zeros terminates each string, and another byte of zeros terminates the set of strings.

Following the last byte of zeros is a set of initial arguments that the operating system passes to a program. This set of arguments contains a word count followed by an ASCII string. If the file is in the current directory, the ASCII string contains the drive and pathname of the executable program as passed to the EXEC function call. If the file is not in the current directory, EXEC concatenates the name of the file with the name of the path. Programs may use this area to determine where the program was loaded.

·· The environment built by the command processor contains at least a comspec= string (the parameters on comspec define the path that MS-DOS uses to locate command.com on disk). The last path and prompt commands issued are also in the environment, along with any environment strings you have defined with the MS-DOS set command.

·· EXEC passes a copy of the invoking process environment. If your application uses a "keep process" concept, you should be aware that the copy of the environment passed to you is static. That is, it will not change even if you issue subsequent set, path, or prompt commands. Conversely, any modification of the passed environment by the application is not reflected in the parent process environment. For instance, a program cannot change the MS-DOS environment values as the set command does.

·· The Disk Transfer Address (DTA) is set to 80H (default DTA in the Program Segment Prefix). The Program Segment Prefix contains file control blocks at 5CH and 6CH. MS-DOS formats these blocks using the first two parameters that you typed when entering the command. If either parameter contained a pathname, then the corresponding FCB contains only the valid drive number. The filename field is not valid.

·· An unformatted parameter area at 81H contains all the characters typed after the command (including leading and embedded delimiters), with the byte at 80H set to the number of characters. If you type <, >, or parameters on the command line, they do not appear in this area (nor the filenames associated with them). Redirection of standard input and output is transparent to applications.

·· Offset 6 (one word) contains the number of bytes available in the segment.

·· Register AX indicates whether the drive specifiers (entered with the first two parameters) are valid, as follows:

AL=FF if the first parameter contained an invalid drive specifier (otherwise AL=00)

AH=FF if the second parameter contained an invalid drive specifier (otherwise AH=00)

·· Offset 2 (one word) contains the segment address of the first byte of unavailable memory. Programs must not modify addresses beyond this point unless these addresses were obtained by allocating memory via Function 48H (Allocate Memory).

For Executable (.exe) Programs:

·· DS and ES registers point to the Program Segment Prefix.

·· CS,IP,SS, and SP registers contain the values that Microsoft link sets in the .exe image.

For Executable (.com) Programs:

·· All four segment registers contain the segment address of the initial allocation block that starts with the Program Segment Prefix control block.

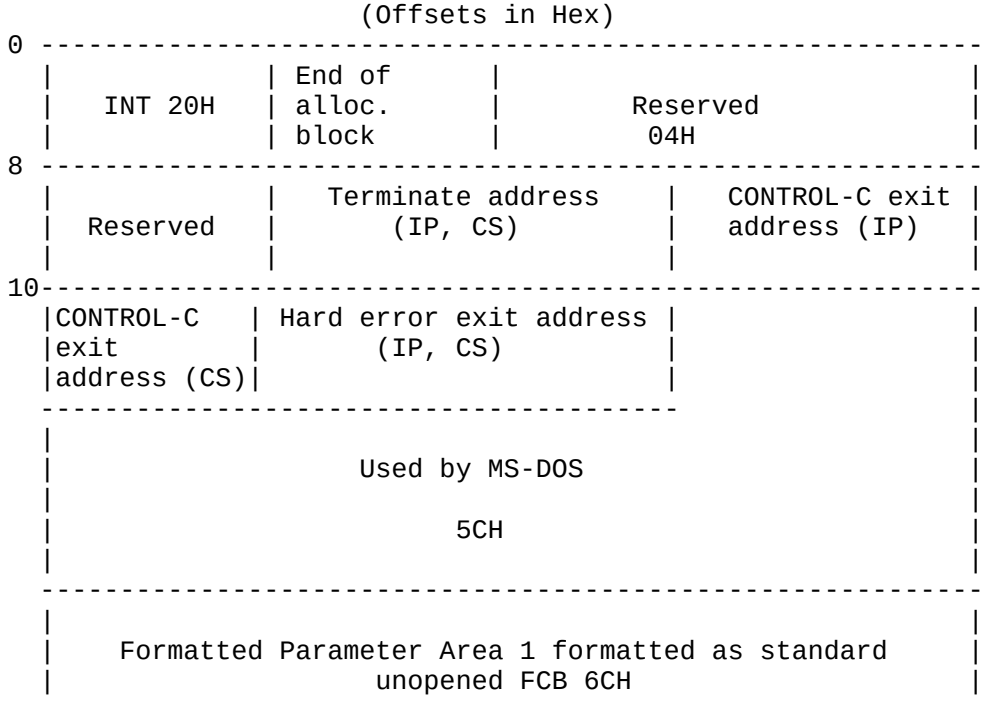
·· .com programs allocate all of user memory. If the program invokes another program through Function 4BH (EXEC), it must first free some memory through Function 4AH (Set Block) to provide space for the program being executed.

·· The Instruction Pointer (IP) is set to 100H.

·· The Stack Pointer register is set to the end of the program's segment. The segment size at offset 6 is reduced by 100H to allow for a stack of that size.

·· A .com program places a word of zeros on top of the stack. Then by doing a RET instruction last, your program can exit to command.com. This method assumes, however, that you have maintained your stack and code segments.

Figure 4.1 illustrates the format of the Program Segment Prefix. All offsets are in hexadecimal.



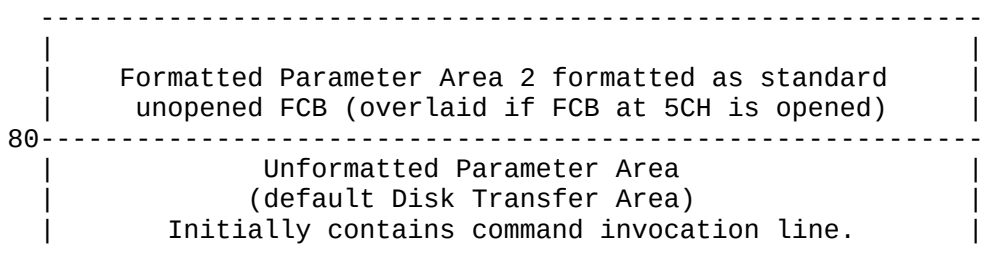


Figure 4.1 Program Segment Prefix

.....
Important
  Programs must not alter any part of the Program Segment Prefix below
  offset 5CH.
.....

Chapter 5 National Language Support

.....

5.1 Introduction

5.2 National Language Support Calls

5.3 Font Files

5.3.1 Font File Structure

5.3.1.1 File Header

5.3.1.2 Information Header

5.3.1.3 Code Page Entry Header

5.3.1.4 Font Data Header

5.3.1.5 Font Header

5.1 Introduction

National language support for this version of MS-DOS 3.3 includes these major features:

- Country-dependent information
- Support for national keyboard layouts
- Programming interfaces for national language support
- Utility commands

Country-dependent information is available on a per-country basis and includes the following:

- Time, date, and currency

- Lowercase-to-uppercase character-conversion tables

- Collating sequence for character sorting

- Valid single-byte characters used in filenames

Selectable keyboard support for different keyboard layouts is provided.

The MS-DOS 3.3 programming interfaces for national language support allow applications to use the country-dependent information just described. To access this information, applications do not need to change the current country code of the system.

Utility commands allow the user to select the keyboard layout and system country code.

This version of MS-DOS does not support right-to-left national languages.

5.2 National Language Support Calls

The following function calls allow an application to tailor its operation to the current country code and to accept or change the current code page. A country code defines the country in which you live or work. MS-DOS uses this code to prepare and assign default code pages for your system. A code page is a table that defines the character set you are using. A character set is a country-specific or language-specific group of characters that are translated from the code page table and displayed on your screen or printer. Each code page character set contains 256 characters.

The following function calls are also used by MS-DOS 3.3 to support the National Language requirements:

- Function 44H, Code 0CH (Generic IOCtl)--supports code page switching on a per-device basis.

- Function 65H (Get Extended Country Information)--returns standard country information, and points to related case-map or collating tables.

- Function 66H (Get/Set Global Code Page)--gets or sets the code page used by the kernel and by all devices.

These functions support access to country-dependent information, all of which resides in one file named country.sys.

5.3 Font Files

Font files, also called code page information files, contain the images of code page character sets for use by console-screen or printer devices. These font files are identified by a filename extension of .cpi. Four font files are included with MS-DOS 3.3:

Font file	Supported device
ega.cpi	Color console used with an EGA card
lcd.cpi	Liquid crystal display
4201.cpi	IBM Proprinter
5202.cpi	Quietwriter III printer

5.3.1 Font File Structure

The contents of printer or console-screen font files are structured as follows:

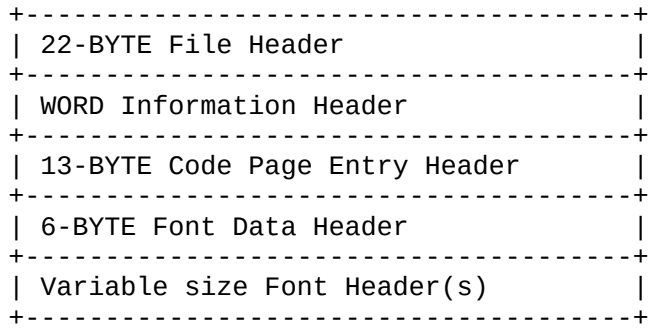


Figure 5.1 Font File Structure

The font file fields are described in the following sections.

5.3.1.1 File Header

Each file must begin with a file header that includes the following:

Length	Parameter
8 BYTES	File tag
8 BYTES	Reserved
WORD	Number of pointers
2 WORDS	Offset

where:

File tag begins with the byte 0FFH and is followed by a string "font " (seven characters).

Reserved is eight bytes of zeros.

Number of pointers is the number of pointers in the header. For MS-DOS 3.3, the value of this word should be 1.

Offset is the two-word offset from the beginning of the file.

5.3.1.2 Information Header

Following the file header is a one-word information header:

Length	Parameter
WORD	Number of code pages

where:

Number of code pages is the number of code page entries in the file.

5.3.1.3 Code Page Entry Header

For each code page entry, a header in the following format is included in the font file:

Length	Parameter
WORD	Length
WORD	Pointer
WORD	Device type
8 BYTES	Device subtype
WORD	Code page ID
WORD	Reserved
2 WORDS	Offset

where:

Length is the size of the code page entry header.

Pointer points to the next code page entry header (last header=0, 0).

Device type is 1 if the device is a console screen, or 2 if the device is a printer.

Device subtype names the type of console screen or printer. This field also determines the name of the font file. For example, if the subtype is "CGA," the font file name is cga.cpi

Code page ID defines a valid three-digit code page identification number. Valid code page numbers are 437, 850, 860, 863, and 865.

Reserved is eight bytes of zeros.

Offset is a pointer to the Font Data Header.

5.3.1.4 Font Data Header

The Font Data Header includes the following fields:

Length	Parameter
WORD	Reserved
WORD	Number of fonts
WORD	Length of font data

where:

Reserved must be 1.

Number of fonts is equal to the number of fonts defined in the font file.

Length of font data is equal to the size of the font-data portion of the font file.

5.3.1.5 Font Header

The font-data portion of a font file will vary for each device. The structure of the font-data portion consists of a set of data for each font type. The following illustrates the data portion of a font file for a console-screen device:

```
font_header:
   db   16, 8             ; character pixels
```

```
                            ; (rows, columns)
   db   0, 0                ; aspect ratio (unused)
   dw   256                 ; number of characters in set


len_data   equ ($ - font_header)
```

Chapter 6 .EXE File Structure and Loading

.....

6.1 Format of a File Header

6.2 The Relocation Table

.....

Note
  This chapter describes .exe file structure and loading procedures
  for systems that use a version of MS-DOS earlier than 2.0. For MS-DOS
  versions 2.0 and later, use Function 4B00H (Load and Execute a Program)
  to load (or load and execute) an .exe file.
.....

The .exe files produced by link consist of two parts:

- Control and relocation information
- The load module

The control and relocation information is at the beginning of the file in an area called the header. Immediately following this header is the load module.

6.1 Format of a File Header

The header is formatted as follows (note that offsets are in hexadecimal):

Offset	Contents
0-1	Must contain 4DH, 5AH.
2-3	Number of bytes contained in last page; useful for reading
Offset	Contents
#2-3	Number of bytes contained in last page; useful for reading overlays.
4-5	Size of the file in 512-byte pages, including the header.
6-7	Number of relocation entries in table.
8-9	Size of the header in 16-byte paragraphs. Used to locate the beginning of the load module in the file.
AH-BH	Minimum number of 16-byte paragraphs required above the end of the loaded program.
CH-DH	Maximum number of 16-byte paragraphs required above the end of the

loaded program. If both minalloc and maxalloc are 0, the program is loaded as high as possible.

EH-FH Initial value to be loaded into stack segment before starting program execution. Must be adjusted by relocation.

Offset Contents
#
10-11 Value to be loaded into the SP register before starting program execution.

12-13 Negative sum of all the words in the file.

14-15 Initial value to be loaded into the IP register before starting program execution.

16-17 Initial value to be loaded into the CS register before starting program execution. Must be adjusted by relocation.

18-19 Relative byte offset from beginning of run file to relocation table.

1AH-1BH The number of the overlay as generated by link.

6.2 The Relocation Table

The relocation table that follows the formatted area above, consists of a variable number of relocation items. Each relocation item contains two fields: a two-byte offset value, followed by a two-byte segment value. These two fields contain the offset into a word's load module. This item requires modification before the module is given control. The following steps describe this process:

1. The formatted part of the header is read into memory. Its size is 1BH.

2. MS-DOS allocates a portion of memory depending on the size of the load module and the allocation numbers (AH-BH and CH-DH). MS-DOS then attempts to allocate 0FFFH paragraphs. This attempt always fails, and returns the size of the largest free block. If this block is smaller than minalloc and loadsize, there is no memory error. But if this block is larger than maxalloc and loadsize, MS-DOS allocates (maxalloc + loadsize). Otherwise, it allocates the largest free block of memory.

3. A Program Segment Prefix is built in the lowest part of the allocated memory.

4. MS-DOS calculates the load module size (using offsets 4-5 and 8-9) by subtracting the header size from the file size. The actual size is adjusted down based on the contents of offsets 2-3. The operating system determines (based on the setting of the high/low load switch) an appropriate segment, called the start segment, where it loads the load module.

5. The load module is read into memory beginning with the start segment.

6. The items in the relocation table are read into a work area.

7. MS-DOS adds the segment value of each relocation table item to the start segment value. This calculated segment, plus value, points

to the module to which the start segment value is added. The result is then placed back into the word in the load module.

8. Once all relocation items have been processed, the operating system sets the SS and SP registers, using the values in the header. MS-DOS then adds the start segment value to SS and sets the ES and DS registers to the segment address of the Program Segment Prefix. The start segment value is then added to the header CS register value. The result, along with the header IP value, is the initial CS:IP to transfer to before starting execution of the program.

Chapter 7 Microsoft Relocatable Object Module Formats

.....

7.1 Introduction

7.1.1 Definition of Terms

7.2 Module Identification and Attributes

7.2.1 Segment Definition

7.2.2 Addressing a Segment

7.2.3 Symbol Definition

7.2.4 Indices

7.3 Conceptual Framework for Fixups

7.3.1 Self-Relative Fixup

7.3.2 Segment-Relative Fixup

7.4 Record Sequence

7.5 Introducing the Record Formats

7.5.1 Sample Record Format (SAMREC)

7.5.2 T-Module Header Record (THEADR)

7.5.3 L-Module Header Record (LHEADR)

7.5.4 List of Names Record (LNAMES)

7.5.5 Segment Definition Record (SEGDEF)

7.5.6 Group Definition Record (GRPDEF)

7.5.7 Public Names Definition Record (PUBDEF)

7.5.8 Communal Names Definition Record (COMDEF)

7.5.9 Local Symbols Record (LOCSYM)

7.5.10 External Names Definition Record (EXTDEF)

7.5.11 Line Numbers Record (LINNUM)

7.5.12 Logical Enumerated Data Record (LEDATA)

7.5.13 Logical Iterated Data Record (LIDATA)

7.5.14 Fixupp Record (FIXUPP)

7.5.15 Module End Record (MODEND)

7.5.16 Comment Record (COMENT)

7.6 Microsoft Type Representations for Communal Variables

7.1 Introduction

This chapter presents the object record formats that define the relocatable object language for the 8086, 80186, and 80286 microprocessors. The 8086 object language is the output of all language translators that have an 8086 processor and that will be linked by the Microsoft linker. The 8086 object language is used for input and output for object language processors such as linkers and librarians, and is used in the XENIX, PC-DOS, and MS-DOS operating systems.

The 8086 object module formats let you specify relocatable memory images that may be linked together. These formats also allow efficient use of the memory mapping facilities of the 8086 family of microprocessors.

The following table lists the record formats (each described in this chapter) that Microsoft supports (the abbreviations appear in parentheses):

Table 7.1
Object Module Record Formats

Symbol Definition Records	
Public Names Definition Record	(PUBDEF)
Communal Names Definition Record	(COMDEF)
Local Symbols Record	(LOCSYM)
External Names Definition Record	(EXTDEF)
Line Numbers Record	(LINNUM)
Data Records	
Logical Enumerated Data Record	(LEDATA)
Logical Iterated Data Record	(LIDATA)
T-Module Header Record	(THEADR)
L-Module Header Record	(LHEADR)
List of Names Record	(LNAMES)
Segment Definition Record	(SEGDEF)
Group Definition Record	(GRPDEF)
Fixup Record	(FIXUPP)
Module End Record	(MODEND)
Comment Record	(COMENT)

Note
If an object module contains any undefined values, the behavior of the Microsoft linker is undefined. All undefined values should be considered reserved by Microsoft for future use.

7.1.1 Definition of Terms

The following terms are fundamental to 8086 relocation and linkage:

OMF--Object Module Formats

MAS--Memory Address Space

The 8086 MAS is one megabyte (1,048,576 bytes). Note that the MAS is distinguished from actual memory, which may occupy only a portion of the MAS.

Module

A module is an "inseparable" collection of object code and other information produced by a translator.

T-Module

A T-module is a module created by a translator, such as Pascal or FORTRAN.

The following restrictions apply to object modules:

- Every module should have a name. Translators provide default names (possibly filenames or null names) for T-modules if neither the source code nor the user specifies otherwise.

- Every T-module in a collection of linked modules should have a different name so that symbolic debugging systems can distinguish the various line numbers and local symbols. The Microsoft linker does not require or enforce this restriction.

Frame

A frame is a contiguous region of 64K of memory address space (MAS), beginning on a paragraph boundary (i.e., on a multiple of 16 bytes) or on a selector on the 80286 processor. This concept is useful because the contents of the four 8086 segment registers define four (possibly overlapping) frames; no 16-bit address in the 8086 code can access a memory location outside the current four frames.

LSEG (Logical Segment)

A logical segment (LSEG) is a contiguous region of memory whose contents are determined at translation time (except for address-binding). Neither the size nor the location in MAS are necessarily determined during translation: the size, although partially fixed, may not be final because the linker may combine the LSEG when linking with other LSEGs, forming a single LSEG. So that it can fit in a frame, an LSEG must not be larger than 64K. Thus, a 16-bit offset, from the base of a frame that covers the LSEG, may address any byte in that LSEG.

PSEG (Physical Segment)

This term is equivalent to frame. Some prefer "PSEG" to "frame" because the terms PSEG and LSEG reflect the "physical" and "logical" nature of the

underlying segments.

Frame Number

Every frame begins on a paragraph boundary. The "paragraphs" in MAS can be numbered from 0 through 65,535. These numbers, each of which defines a frame, are called frame numbers.

Group

A group is a collection of LSEGs defined at translation time, whose final locations in MAS have been constrained so that at least one frame exists that covers (contains) every LSEG in the collection.

The notation "Gr A(X,Y,Z,)" means that LSEGs X, Y, and Z form a group named A. That X, Y, and Z are all LSEGs in the same group does not imply any ordering of X, Y, and Z in MAS, nor does it imply any contiguity between X, Y, and Z.

The Microsoft linker does not currently allow an LSEG to be a member of more than one group.

Canonic

On the 8086 processor, any location in MAS is contained in exactly 4096 distinct frames, but one of these frames can be distinguished because it has a higher frame number. This frame is called the canonic frame of the location. In other words, the canonic frame of a given byte is the frame chosen so that the byte's offset from that frame lies in the range 0 to 15 (decimal).

For example, suppose FOO is a symbol defining a memory location. You would then refer to this frame as the "canonic frame of FOO." Similarly, if S is any set of memory locations, then a unique frame exists that has the lowest frame number in the set of canonic frames of the locations in S. This unique frame is called the canonic frame of the set S. You might refer similarly to the canonic frame of an LSEG or of a group of LSEGs.

Segment Name

LSEGs are assigned Segment Names at translation time. These names serve two purposes:

- During linking they play a role in determining which LSEGs are combined with other LSEGs.
- They are used in assembly source code to specify membership in groups.

Class Name

The translator may optionally assign class names to LSEGs during translation. Classes define a partition on LSEGs: two LSEGs are in the same class if they have the same class name.

The Microsoft linker applies the following semantics to class names: the class name "CODE", or any class name whose suffix is "CODE", implies that all segments of that class contain only code and may be considered read-only. Such segments may be overlaid if you specify the module

containing the segment as part of an overlay.

Overlay Name

The linker may optionally assign an overlay name to LSEGs. The overlay name of an LSEG is ignored by Microsoft language linkers for version 3.00 and later languages, but the standard MS-DOS linker supports it.

Complete Name

The complete name of an LSEG consists of the segment name, class name, and overlay name. The linker combines LSEGs from different modules if their complete names are identical.

7.2 Module Identification and Attributes

A module header record, which provides a module name, is always the first record in a module. In addition to having a name, a module may represent a main program and may have a specified starting address. When linking multiple modules together, you should give only one module with the main attribute. If more than one main module appears, the first takes precedence.

In summary, modules may or may not be main and may or may not have a starting address.

7.2.1 Segment Definition

A module is a collection of object code defined by a sequence of records that a translator produces. The object code represents contiguous regions of memory whose contents the linker determines during translation. These regions are LSEGs. A module defines the attributes of each LSEG. The segment definition record (SEGDEF) is responsible for maintaining all LSEG information (name, length, memory alignment, etc.). The linker requires the LSEG information when you combine multiple LSEGs and when it establishes segment addressability. The SEGDEF records must follow the first header record.

7.2.2 Addressing a Segment

The 8086 addressing mechanism provides segment base registers from which you may address a 64K-byte region of memory (a Frame). There is one code segment base register (CS), two data segment base registers (DS, ES), and one stack segment base register (SS).

The possible number of LSEGs that may make up a memory image far exceeds the number of available base registers. Thus, base registers may require frequent loading. This would be the case in a modular program with many small data and/or code LSEGs.

Since such frequent loading of base registers is undesirable, it is a good strategy to collect many small LSEGs together into a single unit that will fit in one memory frame. Then all the LSEGs may be addressed using the same base register value. This addressable unit is a group and has been defined earlier in Section 7.1.1, "Definition of Terms."

To establish addressability of objects within a group, you must explicitly define each group in the module. The group definition record (GRPDEF) lists

constituent segments by their segment names.

The GRPDEF records within a module must follow all SEGDEF records because GRPDEF records will reference SEGDEF records in defining a Group. The GRPDEF records must also precede all other records except header records, which the linker must process first.

7.2.3 Symbol Definition

The Microsoft linker supports three different types of records belonging to the class of symbol definition records. The types are public names definition records (PUBDEFs), communal names definition records (COMDEFs), and external names definition records (EXTDEFs). You use these record types to define globally visible procedures and data items and to resolve external references.

7.2.4 Indices

"Index" fields appear throughout this chapter. An index is an integer that selects a particular item from a collection of items; for example: name index, segment index, group index, external index, type index, etc.

.....
Note
  An index is normally a positive number. The index value zero is reserved, and may carry a special meaning depending on the type of index (for example, a segment index of zero specifies the "Unnamed" absolute pseudo-segment; a type index of zero specifies the "Untyped type.")
.....

In general, indices must assume values that are quite large (that is, much larger than 255). Nevertheless, a great number of object files contain no indices with values greater than 50 or 100. Therefore, indices are encoded in one or two bytes, as required.

The high-order (left-most) bit of the first (and possibly the only) byte determines whether the index occupies one byte or two. If the bit is 0, the index is a number between 0 and 127, occupying one byte. If the bit is 1, the index is a number between 0 and 32K-1, occupying two bytes, and is determined as follows: the low-order eight bits are in the second byte, and the high-order seven bits are in the first byte.

7.3 Conceptual Framework for Fixups

A fixup is a modification to object code that achieves address binding that a translator requested and a linker performed.

.....
Note
  This is the linker's definition of fixup. Nevertheless, the linker can modify object code (make a "fixup") that does not conform to this definition. For example, binding code to either hardware or software floating-point subroutines is a modification to an operation code, which is treated as an address. The previous definition of fixup is not intended to disallow or discourage modifications to the object code.
.....

8086-family translators need four kinds of data to specify a fixup:

- The place and type of a Location to be fixed up.

·· One of two possible fixup modes.

·· A target, which is the memory address that Location must refer to.

·· A frame that defines a context in which the reference takes place.

Location--There are five types of Locations: a pointer, a base, an offset, a hibyte, and a lobyte.

The vertical alignment of the following figure illustrates four points (remember that the high-order byte of a word in 8086 memory is the byte with the higher address):

·· A base is the high-order word of a pointer (the linker doesn't care whether the low-order word of the pointer is present).

·· An offset is the low-order word of a pointer (the linker doesn't care whether the high-order word follows).

·· A hibyte is the high-order half of an offset (the linker doesn't care whether the low-order half precedes).

·· A lobyte is the low-order half of an offset (the linker doesn't care whether the high-order half follows).

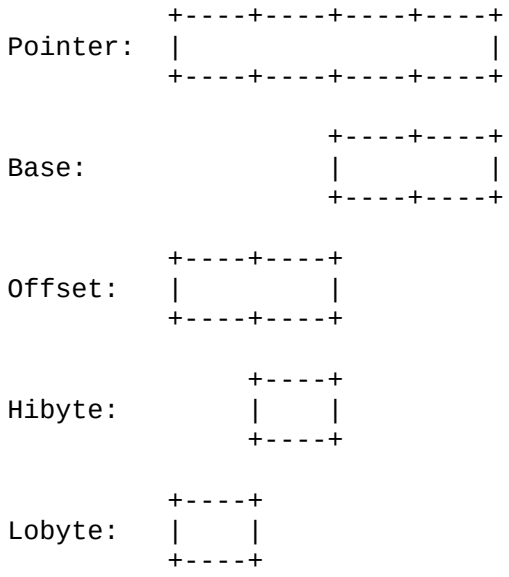


Figure 7.1 Location Types

A Location is specified by two kinds of data: the Location type, and where the Location is.

The Location type is specified by the LOC field in the FIXUPP record's LOCAT field; where the Location is is specified by the Data Record Offset field in the same LOCAT field.

Mode--The Microsoft linker supports two kinds of fixups: self-relative and segment-relative.

Self-relative fixups support the 8-bit and 16-bit offsets used in CALL, JUMP, and SHORT-JUMP instructions. Segment-relative fixups support all other addressing modes of the 8086.

Target--The target is the location in MAS that the linker references. (More explicitly, the linker considers the target the lowest byte in the object that it is referencing.) The linker specifies a target by one of six methods. There are three "primary" methods and three "secondary" ones. Each primary method of specifying a target uses two kinds of data: an index number X, and a displacement D.

Method	Explanation
(T0)	X is a segment index. The target is the Dth byte in the LSEG that the segment index identifies.
(T1)	X is a group index. The target is the Dth byte in the LSEG that the group index identifies.
(T2)	X is an external index. The external index identifies the external name that (eventually) gives the address of a byte. The Dth byte following this byte is the target.

Each secondary method of specifying a target uses only one item of data--the index number X; this assumes an implicit displacement equal to zero.

Method	Explanation
(T4)	X is a segment index. The target is the 0th (first) byte in the LSEG that the segment index identifies.
(T5)	X is a group index. The target is the 0th (first) byte in the LSEG in the specified group located (eventually) lowest in MAS.
(T6)	X is an external index. The target is the byte whose address is the external name that the external index identifies.

The following nomenclature describes a target:

Nomenclature	Method
Target: SI(segment name), displacement	[T0]
Target: GI(group name), displacement	[T1]
Target: EI(symbol name), displacement	[T2]
Target: SI (segment name)	[T4]
Target: GI (group name)	[T5]
Target: EI (symbol name)	[T6]

The following examples illustrate how this notation is used:

Sample Nomenclature	Explanation
Target: SI(CODE), 1024	The 1025th byte in the segment CODE.
Target: GI(DATAAREA)	The location in MAS of a group called DATAAREA.
Target: EI(SIN)	The address of the external subroutine SIN.
Target: EI(PAYSCHEDULE), 24	The 24th byte following the location of an external data structure called PAYSCHEDULE.

Frame--Every 8086 memory reference is to a location contained within a frame. This frame is designated by the content of a segment register. For the linker to form a correct, usable memory reference, it must know what the target is, and to which frame the reference is being made. Thus, every fixup specifies such a frame, in one of six methods. Some methods

use data, X, which is in the index number. Other methods require no data.

The five methods of specifying frames are as follows:

Method	Explanation
(F0)	X is a segment index. The frame is the canonic frame of the LSEG that the segment index defines.
(F1)	X is a group index. The frame is the canonic frame defined by the group (that is, the canonic frame defined by the LSEG in the group located (eventually) lowest in MAS).
(F2)	X is an external index. The frame is determined when the linker finds the external name's public definition. There are two cases:

Method	Explanation
	Case (F2a): The linker defines the symbol relative to some LSEG, and there is no associated group. The linker also specifies the LSEG's canonic frame.
	Case (F2c): Regardless of how the linker defines the symbol, there is an associated group. And the linker specifies the canonic frame of the group. (The Group Index field of the PUBDEF record specifies the group.)

(F4)	No X. The frame is the canonic frame of the LSEG that contains Location.
(F5)	No X. The target determines the frame. There are three cases:

Method	Explanation
	Case (F5a): The target specifies a segment index: in this case, the frame is determined as in (F0).
	Case (F5b): The target specifies a group index: in this case, the frame is determined as in (F1).
	Case (F5c): The target specifies an external index: in this case, the frame is determined as in (F2).

The nomenclature that describes frames is similar to the above nomenclature for targets.

Nomenclature	Method
Frame: SI (segment name)	[F0]
Frame: GI (group name)	[F1]
Frame: EI (symbol name)	[F2]
Frame: Location	[F4]
Frame: target	[F5]
Frame: None	[F6]

For an 8086 memory reference, the frame specified by a self-relative reference is usually the canonic frame of the LSEG that contains Location.

Also, the frame specified by a segment-relative reference is the canonic frame of the LSEG that contains the target.

7.3.1 Self-Relative Fixup

A self-relative fixup works as follows: Location implicitly defines a memory address-namely, the address of the byte following Location (because at the time of a self-relative reference, the 8086 IP (Instruction Pointer) is pointing to the byte following the reference).

For 8086 self-relative references, if either the Location or the target is outside the specified frame, the linker gives a warning. Otherwise, there is a unique l6-bit displacement that, when added to the address implicitly defined by Location, yields the relative position of the target in the frame.

- If Location is an offset, the linker adds the displacement to Location (modulo 65,536) and reports no errors.

- If Location is a lobyte, the displacement must be within the range {-128:127}; otherwise, the linker gives a warning. The linker adds the displacement to Location (modulo 256).

- If Location is a base, pointer, or hibyte, it is unclear what the translator intended, so the linker's action is undefined.

7.3.2 Segment-Relative Fixup

A segment-relative fixup operates as follows: a nonnegative 16-bit number, FBVAL, is defined as the frame number of the frame or selector value that the fixup specifies. A signed 20-bit number, FOVAL, is defined as the distance from the base of the frame to the target. If this signed 20-bit number is less than 0 or greater than 65,535, the linker reports an error. Otherwise, the linker uses FBVAL and FOVAL to fix up Location in the following fashion:

- If Location is a pointer, the linker adds FBVAL (modulo 65,536) to the high-order word of pointer, and adds FOVAL (modulo 65,536) to the low-order word of pointer.

- If Location is a base, the linker adds FBVAL (modulo 65,536) to the base and ignores FOVAL.

- If Location is an offset, the linker adds FOVAL (modulo 65,536) to the offset and ignores FBVAL.

- If Location is a hibyte, the linker adds (FOVAL/256) (modulo 256) to the hibyte and ignores FBVAL. (The division indicated is integer division; that is, the linker discards the remainder.)

- If Location is a lobyte, the linker adds (FOVAL modulo 256) (modulo 256) to the lobyte and ignores FBVAL.

7.4 Record Sequence

A object code file must contain a sequence of (one or more) modules, or a library containing zero or more modules. The following syntax shows the valid record ordering necessary to form a module. In addition, the given semantic rules provide information about how to interpret the record sequence.

.....
Note
  The description language used in the following syntax is defined in
  WIRTH: CACM, November 1977, vol. 20, no. 11, pp. 822-823. The character
  strings represented by capital letters are not literals but identifiers,
  and are further defined in the record format section.
.....

```
object file  = tmodule

tmodule      = {THEADR | LHEADR} seg-grp {component} modtail

seg_grp      = {LNAMES} {SEGDEF} {EXTDEF | GRPDEF}

component    = data | debug_record

data         = content_def | thread_def |
                     PUBDEF | EXTDEF | COMDEF | LOCSYM

debug_record = LINNUM

content_def  = data_record {FIXUPP}

thread_def   = FIXUPP (containing only Thread fields)

data_record  = LIDATA | LEDATA

modtail      = MODEND
```

The following rules apply:

- A FIXUPP record always refers to the previous data record.

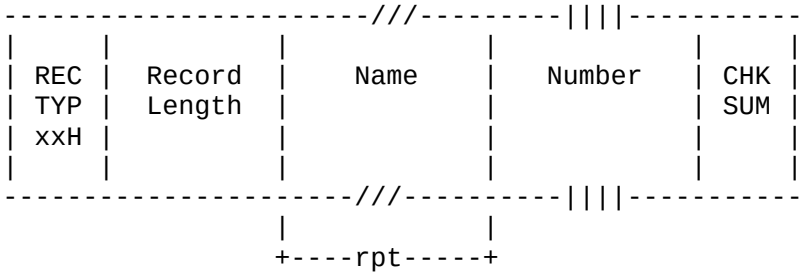
- All LNAMES, SEGDEF, GRPDEF, and EXTDEF records must precede all records that refer to them.

- Comment records may appear anywhere in a file, except as the first or last record in a file or module, or within a content_def.

7.5 Introducing the Record Formats

The following pages present diagrams of record formats in schematic form. Here is a sample record format that illustrates the various conventions:

7.5.1 Sample Record Format (SAMREC)



The Title and Official Abbreviation

At the top of the figure is the name of the record format described, with

its official abbreviation. To promote uniformity among various programs, including translators and debuggers, use the abbreviation in both code and documentation. The abbreviation of the record format is always six letters.

The Boxes

Each format is drawn with boxes of two sizes. The narrow boxes represent single bytes. The wide boxes each represent two bytes. The wide boxes with three slashes in the top and bottom represent a variable number of bytes, one or more, depending upon content. The wide boxes with four vertical bars in the top and bottom represent four-byte fields.

RECTYP

The first byte in each record contains a value between 0 and 255, indicating the record type.

Record Length

The second field in each record contains the number of bytes in the record, exclusive of the first two fields, where a field is a 16-bit number--a low byte followed by a high byte.

Name

Any field that indicates a name has the following internal structure: the first byte contains a number between 0 and 127, inclusive, indicating the number of remaining bytes in the field. The remaining bytes are interpreted as a byte string.

Most translators constrain the character set to a subset of the ASCII character set.

Number

A four-byte number field represents a 32-bit unsigned integer, where the first eight bits (least-significant) are stored in the first byte (lowest address), the next eight bits are stored in the second byte, and so on.

Repeated or Conditional Fields

Some portions of a record format contain a field or series of fields that may be repeated one or more times. Such portions are indicated by the "repeated" or "rpt" brackets below the boxes.

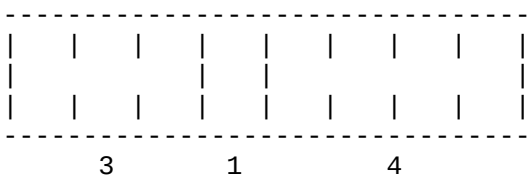
Similarly, some portions of a record format are present only if some given condition is true; these fields are indicated by similar "conditional" or "cond" brackets below the boxes.

CHKSUM

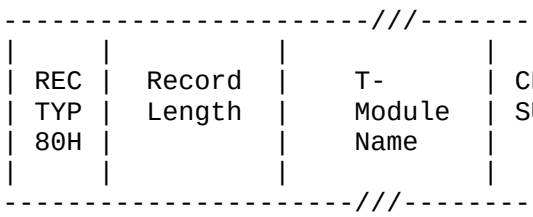
The last field in each record is a check sum, which contains the two's complement of the sum (modulo 256) of all other bytes in the record. Therefore, the sum (modulo 256) of all bytes in the record is zero.

Bit Fields

Sometimes descriptions of contents of fields are at the bit level. Boxes with vertical lines drawn through them represent bytes or words; the vertical lines indicate bit boundaries. Thus, the following byte representation has three bit fields of three, one, and four bits, respectively.



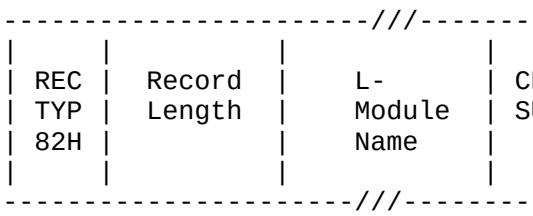
7.5.2 T-Module Header Record (THEADR)



T-Module Name

The T-Module Name field contains the name for the T-module.

7.5.3 L-Module Header Record (LHEADR)

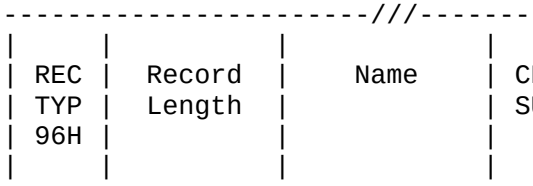


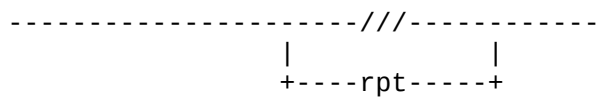
L-Module Name

The L-Module Name field contains the name for the L-module.

Every module output from a translator must have a T-module or L-module header record. The linker requires a THEADR or LHEADR record to come first in the module and ignores any others. The LHEADR record is identical to the THEADR record, except it has a record type of 82H.

7.5.4 List of Names Record (LNAMES)





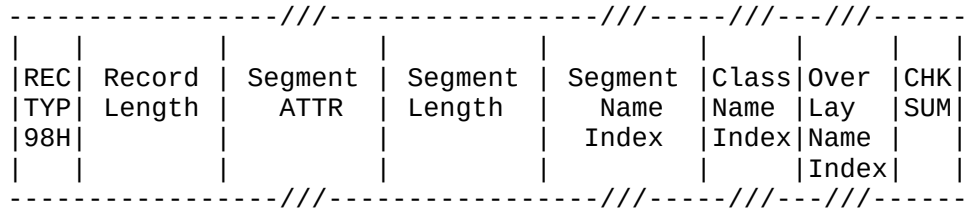
The LNAMES record contains a list of names that the following SEGDEF and GRPDEF records may use as the names of segments, classes, and/or groups.

The order of LNAMES records in a module and the order of names within each LNAMES record imply a mapping of these names to numbers: 1, 2, 3, etc. These numbers are used as "Name Indices" in the Segment Name Index, Class Name Index, and Group Name Index fields of the SEGDEF and GRPDEF records.

Name

This repeatable field provides a name, which may have zero length.

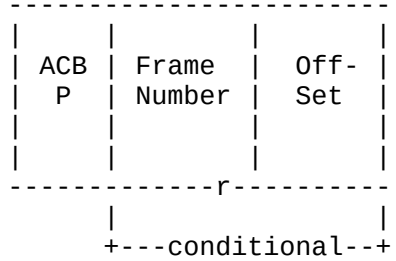
7.5.5 Segment Definition Record (SEGDEF)



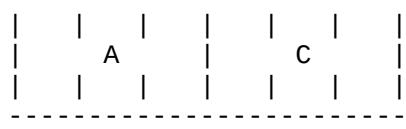
Segment index values 1 through 32,767, which are used in other record types to refer to specific LSEGs, are defined implicitly by the sequence in which SEGDEF records appear in the object file.

SEG ATTR

The SEG ATTR field provides information on various attributes of a segment, and has the following format:



The ACBP byte contains four numbers--the A, C, B, and P attribute specifications. This byte has the following format:



A (Alignment) is a 3-bit subfield that specifies the alignment attribute of the LSEG. The semantics are defined as follows:

.....
A=0 SEGDEF describes an absolute LSEG.
A=1 SEGDEF describes a relocatable, byte-aligned LSEG.
A=2 SEGDEF describes a relocatable, word-aligned LSEG.

A=3 SEGDEF describes a relocatable, paragraph-aligned LSEG.
A=4 SEGDEF describes a relocatable, page(256-byte)-aligned LSEG.

If A=0, the Frame Number and Offset fields are present. With the Microsoft linker, you may use absolute segments for addressing only; for example, to define the starting address of a ROM and to define symbolic names for addresses within the ROM. The linker ignores any data that belongs to an absolute LSEG, and issues a warning if absolute segments are defined for a program that runs in protected mode.

C (Combination) is a 3-bit subfield that specifies the Combination attribute of the LSEG. Absolute segments (A=0) must have combination zero (C=0). For relocatable segments, the C field encodes a number (0,1,2,3,4,5,6, or 7) that indicates how the segment can be combined. One way to interpret this attribute is to consider how two LSEGs are combined.

For example, suppose that X and Y are LSEGs, and that Z is the LSEG resulting from the combination of X and Y. Let LX and LY be the lengths of X and Y, and let MXY denote the maximum of LX, LY. Now, to accommodate the alignment attribute of Y, let G be the length of any gap required between the X and Y components of Z. Then, let LZ denote the length of the (combined) LSEG, Z; let dx (0··dx<LX) be the offset in X of a byte, and similarly, let dy be the offset (of a byte) in Y.

The following table gives the length LZ of the combined LSEG, Z, and the offsets dx' and dy' in Z for the bytes corresponding to dx in X, and to dy in Y.

Table 7.2
Combination Attribute Example

C	LZ	dx'	dy'	
2	LX+LY+G	dx	dy+LX+G	"Public"
5	LX+LY+G	dx	dy+LX+G	"Stack"
6	MXY	dx	dy	"Common"

Table 7.2 has no lines for C=0, 1, 3, 4, or 7. C=0 indicates that the relocatable LSEG may not be combined; C=1 and C=3 are undefined. C=4 and C=7 are treated the same as C=2.

B (Big) is a 1-bit subfield, which, if set to 1, indicates that the segment length is exactly 64K (65,536 bytes). In this case, the Segment Length field must contain zero.

The P field must always be zero.

The Frame Number and Offset fields (present only for absolute segments, A=0) specify the placement in MAS of the absolute segment. Offset is in the range between 0 and 15, inclusive. If you want an offset value larger than 15, you should adjust the frame number.

Segment Length

The Segment Length field gives a segment's length in bytes. This length may be zero. If it is, the linker does not delete the segment from the module. The Segment Length field is only large enough to hold numbers from 0 to 64K-1, inclusive. To give the segment a length of 64K, you must use the B attribute bit in the ACBP field (see SEG ATTR in this section).

Segment Name Index

The segment name is a name that a programmer or translator assigns to the segment; for example, CODE, DATA, TAXDATA, MODULENAME_CODE, or STACK. The Segment Name Index field provides the segment name by indexing into the list of names provided by the LNAMES record.

Class Name Index

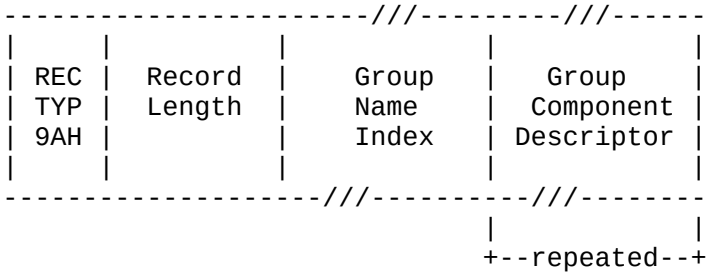
The class name is a name the programmer or translator assigns to a segment. If none is assigned, the name is null, and has a length of zero. The purpose of a class name is to let the programmer define a "handle" to order the LSEGs in MAS; for example, RED, WHITE, BLUE; or ROM FASTRAM, DISPLAYRAM. The Class Name Index field provides the class name by indexing into the list of names provided by the LNAMES record.

Overlay Name Index

The overlay name is a name that the translator and/or the linker, at the programmer's request, applies to a segment. The overlay name, like the class name, may be null. The Overlay Name Index field provides the overlay name by indexing into the list of names provided by the LNAMES record.

.....
Note
  Microsoft language linkers (versions 3.00 and later) ignore the Overlay Name Index field, but the standard MS-DOS linker supports it.
.....

7.5.6 Group Definition Record (GRPDEF)



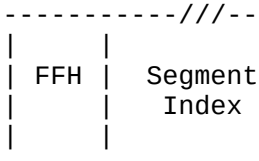
Group Name Index

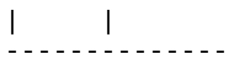
The linker may reference a collection of LSEGs with the group name. Most importantly, when the LSEGs are eventually fixed in MAS, a frame must exist that "covers" every LSEG of the group.

The Group Name Index field provides the group name by indexing into the list of names provided by the LNAMES record.

Group Component Descriptor

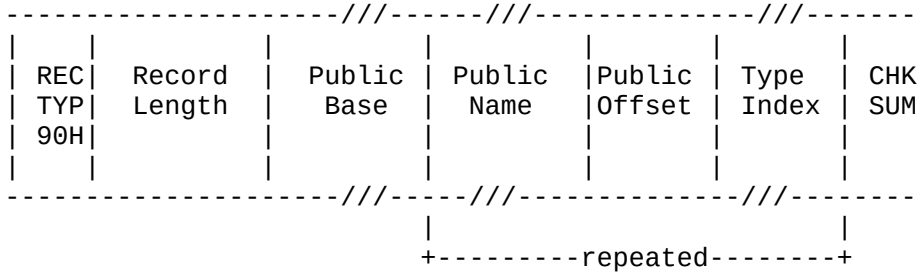
This repeatable field has the following format:





The first byte of the Group Component Descriptor field contains 0FFH; the descriptor contains one field, which is a segment index that selects the LSEG described by a preceding SEGDEF record.

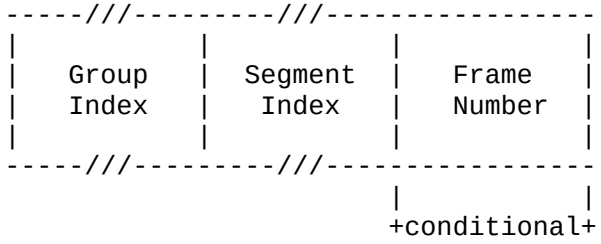
7.5.7 Public Names Definition Record (PUBDEF)



The PUBDEF record provides a list of one or more public names. For each name, three kinds of data are provided: (1) a base value for the name, (2) the offset value of the name, and (3) the type of entity represented by the name.

Public Base

The Public Base field has the following format:



The Group Index field has a format given earlier, and contains a number between 0 and 32,767, inclusive. A nonzero value in the Group Index field associates a group with the public symbol, and is used as described in case (F2c) of Section 7.3, "Conceptual Framework for Fixups." A zero value in the Group Index field indicates that there is no associated group.

The Segment Index field has a format given earlier, and contains a number between 0 and 32,767, inclusive.

A nonzero value in the Segment Index field selects an LSEG. In this case, the location of each public symbol defined in the record is taken as a nonnegative displacement (given by a Public Offset field) from the first byte of the selected LSEG. Also, the Frame Number field must be absent.

A zero value in the Segment Index field means that the defined are absolute, and that the absolute addresses of the symbols are the values in the Public Offset field. The Group Index field is ignored.

The Frame Number field contains a frame number only if the value of the Segment Index field is zero. The linker ignores this field.

A nonzero value in the Group Index field selects some group. This group is taken as the "frame of reference" for references to all public symbols defined in this record. That is, the linker performs the following actions:

·· The linker converts any fixup of the form:

Target: EI(P)

Frame: Target

(where P is a public symbol in this PUBDEF record) to a fixup of the form:

Target: SI(L),d

Frame: GI(G)

where SI(L) and d are provided by the Segment Index and Public Offset fields. (The "normal" action would have the frame specifier in the new fixup be the same as in the old fixup: Frame:Target.)

·· When the linker converts the value of a public symbol, as defined by the Segment Index, Public Offset, and (optionally) Frame Number fields, to a {base,offset} pair, the base part is the base of the indicated group.

A zero value in the Group Index field selects no group. The linker does not alter the frame specification of fixups referencing the symbol, and takes, as the base part of the absolute value of the public symbol, the canonic frame of the segment (either LSEG or PSEG) determined by the Segment Index field.

Public Name

The Public Name field gives the name of the object whose location in MAS the linker makes available to other modules. The name must contain one or more characters.

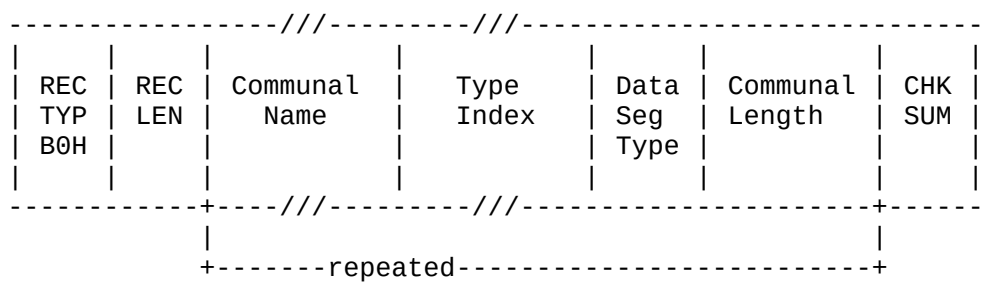
Public Offset

The Public Offset field is a 16-bit value. It is either the offset of the public symbol with respect to an LSEG (if the segment index is greater than zero), or the offset of the public symbol with respect to the specified frame (if the segment index is equal to zero).

Type Index

The Type Index field identifies a single preceding TYPDEF (Type Definition Record), which contains a descriptor for the type of entity represented by the public symbol. The linker ignores this field.

7.5.8 Communal Names Definition Record (COMDEF)



The COMDEF record provides a list of one or more Communal Names, which

define communal variables. A communal variable is an unitialized public variable whose final size and location are not fixed during compiling.

Communal variables are similar to FORTRAN common blocks in that if you are linking object modules that each declare a communal variable, then the size of that variable is the largest of the declared variables. In the C language, all uninitialized public variables are communal. The following example shows three different declarations of the same C communal variable:

```
char    foo[4];         /* In file a.c */
char    foo[1];         /* In file b.c */
char    foo[1024];      /* In file c.c */
```

If the objects produced from a.c, b.c, and c.c are linked together, the linker allocates 1024 bytes for the character array "foo."

.....
Note
  This record requires that a COMENT record from the Microsoft
  Extension class appear before it in the object module.
.....

Communal Name

The Communal Name field gives the communal variable name, and must contain one or more characters.

Communal names are treated as external names when an external name is requested elsewhere in the module. Communal names are ordered together with external names for the purpose of referring to an external name by its index. (See the description of the EXTDEF record later in this section for more details on external names.)

Type Index

The Type Index field is ignored by the Microsoft linker.

Data Segment Type

The Data Segment Type field is a single byte that describes the data segment in which the communal variable resides. It can contain the following values:

    62H (NEAR) = the communal variable is in the default data segment.
    61H (FAR) = the communal variable is not in the default data segment.

Communal Length

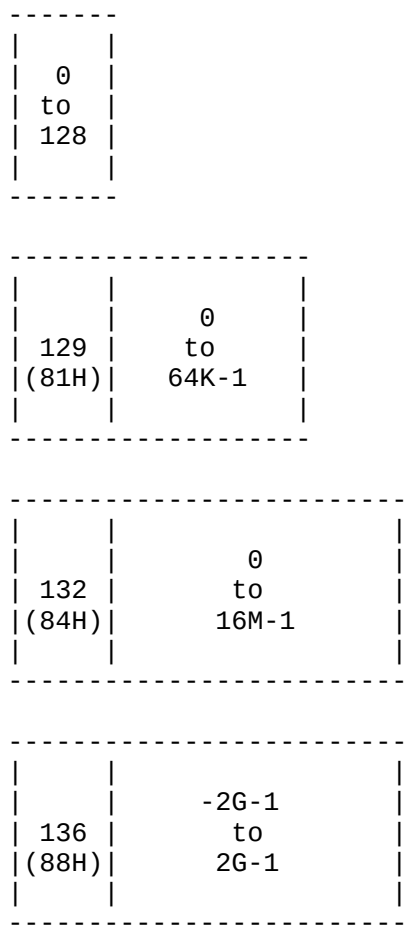
The Communal Length field describes the length of the communal variable o according to its data segment type.

If its value is NEAR (62H), the field represents the length in bytes.

If its value is FAR (61H), the field represents:

```
+----///----+-----///------+
| Number of | Element size |
| elements  | in bytes     |
+----///----+-----///------+
```

The format of all the length fields is as follows:



The first format (single byte), containing a value between 0 and 127, represents the number given.

The second format, with a leading byte containing 129, represents the number contained in the following two bytes.

The third format, with a leading byte containing 132, represents the number contained in the following three bytes.

The fourth format, with a leading byte containing 136, represents the number contained in the following four bytes with its sign extended if necessary.

Link-Time Semantics

A PUBDEF matching a communal variable definition overrides the communal variable definition. Two communal variable definitions match if the names in their definitions match. If two matching definitions disagree whether a communal variable is NEAR or FAR, the linker assumes the variable is NEAR.

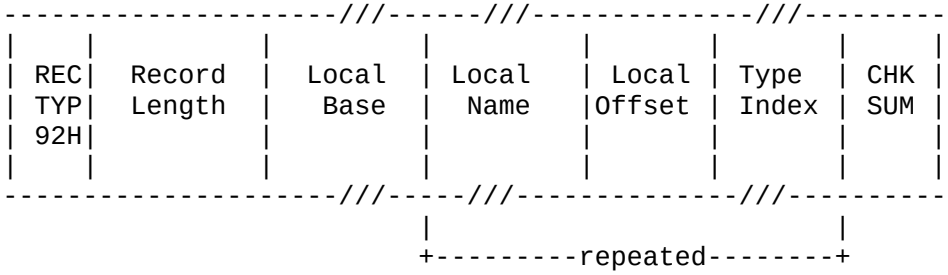
If the variable is NEAR, then its size is the largest of the sizes specified for it. If the variable is FAR, the linker issues a warning if the array element sizes conflict. If these sizes don't conflict, the variable's size is the element size multiplied by the largest number of elements specified. In addition, the sum of the sizes of all NEAR variables must not exceed 64K bytes, and the sum of the sizes of all FAR variables must not exceed the size of the machine's addressable memory space.

HUGE Communal Variables:

A FAR communal variable that is larger than 64K bytes (a HUGE communal variable) resides in segments that are contiguous (on an 8086) or that have consecutive selectors (on an 80286). No other data items reside in the segments occupied by a HUGE communal variable.

If the linker finds matching HUGE and NEAR communal variable definitions, it issues a warning message, since it is impossible for a NEAR variable to be larger than 64K bytes.

7.5.9 Local Symbols Record (LOCSYM)

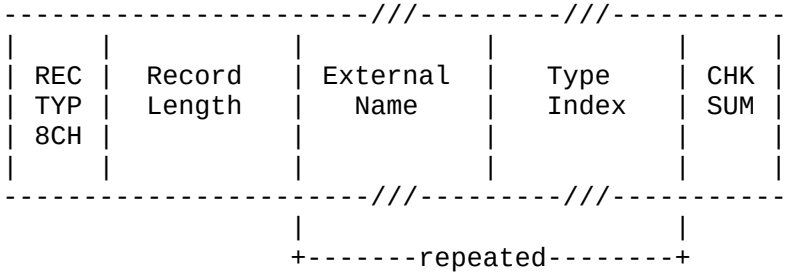


The LOCSYM record provides information for the definition of a local symbol, one that is visible only within the module in which it is defined.

The form and meaning of each of the fields is identical to those in the PUBDEF record.

.....
Note
  The LOCSYM record requires that a COMENT record from the Microsoft
  Extensions class appear before it in the object module. Also, it is
  only recognized by Microsoft language linkers later than version 3.07.
.....

7.5.10 External Names Definition Record (EXTDEF)



The EXTDEF record provides a list of external names, and for each name, the type of object it represents. The linker assigns to each external name the value provided by an identical public name or local name (if such a name is found).

External Name

The External Name field provides the external object name, which must have nonzero length.

Including a name in an EXTDEF record is an implicit request to link the

object file to a module containing the same name declared as a public symbol, unless the name is defined as a local symbol within the same module as the EXTDEF. This request determines whether the external name is referenced within some FIXUPP record in the module.

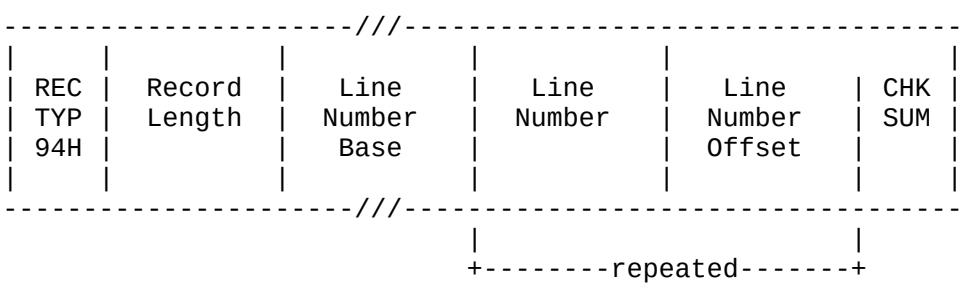
The order of EXTDEF records in a module and the order of external names within each EXTDEF record, together with COMDEF records and communal names, implies a mapping on the set of all external names requested by the module; for example: 1, 2, 3, etc. So to refer to a particular external name, the linker uses these numbers as "external indices" in the Target Datum and/or Frame Datum fields of FIXUPP records.

External indices may not reference forward. For example, an EXTDEF defining the kth object must precede any record referring to that object with index k.

Type Index

The Type Index field is ignored by the Microsoft linker, except for linker versions earlier than 3.05, and for object modules lacking the COMENT record from the Microsoft Extensions class, in which case, refer to Section 7.6, "Microsoft Type Representation for Communal Variables."

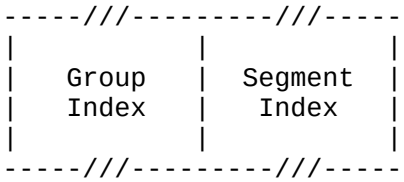
7.5.11 Line Numbers Record (LINNUM)



The LINNUM record allows a translator to relate a line number in source code to the corresponding line in translated code.

Line Number Base

The Line Number Base field has the following format:



The Group Index field is ignored by the Microsoft linker.

The Segment Index field determines the location of the first byte of code corresponding to some source line number.

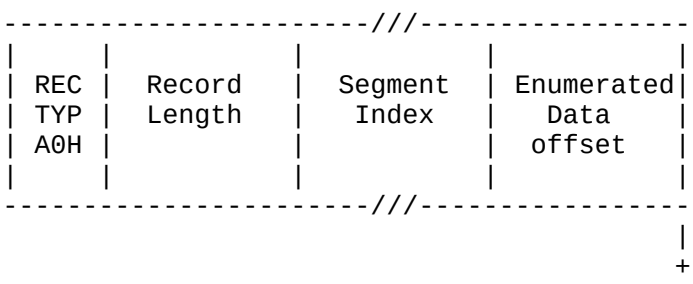
Line Number

The Line Number field provides a binary line number between 0 and 32,767, inclusive. If the high-order bit is not zero, the number is considered undefined.

Line Number Offset

The Line Number Offset field is a 16-bit value, which is the offset of the line number with respect to an LSEG (if the segment index is greater than zero).

7.5.12 Logical Enumerated Data Record (LEDATA)



The LEDATA record provides contiguous data from which the linker may construct a portion of an 8086 memory image.

Segment Index

The Segment Index field, which must be nonzero, specifies an index relative to the SEGDEF records that precede the LEDATA record.

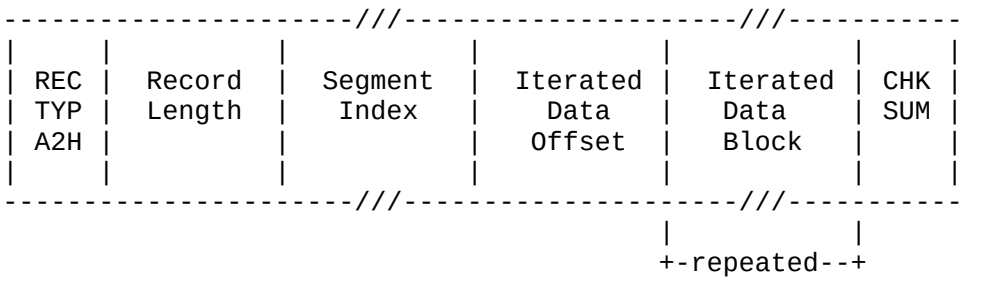
Enumerated Data Offset

The Enumerated Data Offset field specifies an offset that is relative to the base of the LSEG specified by the segment index. The field also defines the relative location of the first byte of the DAT field. Successive data bytes in the DAT field occupy successively higher locations of memory.

DAT

The DAT field provides up to 1024 consecutive bytes of relocatable or absolute data.

7.5.13 Logical Iterated Data Record (LIDATA)



The LIDATA record provides contiguous data from which the linker may construct a portion of an 8086 memory image.

Segment Index

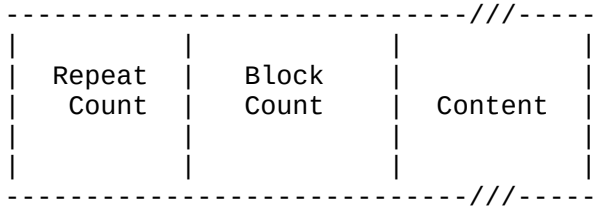
The Segment Index field, which must be nonzero, specifies an index that is relative to the SEGDEF records that precede the LIDATA record.

Iterated Data Offset

The Iterated Data Offset field specifies an offset that is relative to the base of the LSEG specified by the segment index. It also defines the relative location of the first byte in the iterated data block. Successive data bytes in the iterated data block occupy successively higher locations of memory.

Iterated Data Block

This repeated field is a structure specifying the repeated data bytes. It has the following format:



.....
Note
  The linker cannot handle LIDATA records whose iterated Data Blocks are larger than 512 bytes.
.....

Repeat Count

The Repeat Count field specifies the number of times to repeat the Content portion of this iterated data block. The value of the Repeat Count field must be nonzero.

Block Count

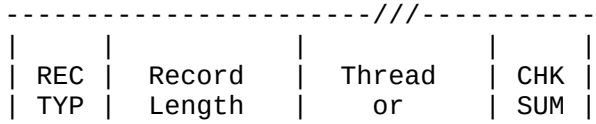
The Block Count field specifies the number of iterated data blocks in the Content portion of this iterated data block. If the Block Count field has a value of zero, the Content portion of the iterated data block is interpreted as data bytes. If the field is nonzero, the Content portion is interpreted as that number of iterated data blocks.

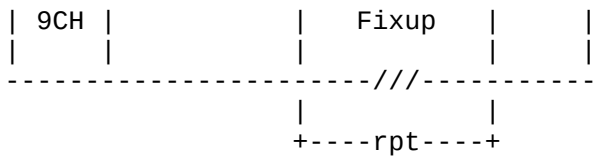
Content

The Content field may be interpreted in one of two ways, depending on the value of the previous Block Count field.

If the Block Count field is zero, this field is a 1-byte count followed by the indicated number of data bytes. But if the Block Count field is nonzero, the Content field is interpreted as the first byte of another iterated data block.

7.5.14 Fixupp Record (FIXUPP)



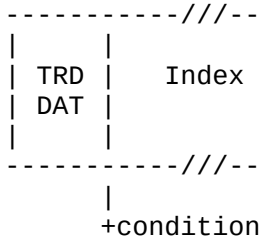


The FIXUPP record specifies zero or more fixups. Each fixup requests a modification (fixup) to a Location within the previous data record. A data record may be followed by more than one FIXUPP record that refers to it. Each fixup is specified by a Fixup field that specifies four kinds of data: a Location, a mode, a target, and a frame. The frame and target may be specified completely within the Fixup field, or by reference to a preceding Thread field.

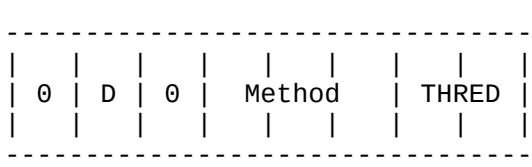
A Thread field specifies a default target or frame that subsequently may be referred to. Eight threads are provided--four for frame specification and four for target specification. Once a thread has specified a target or frame, any Fixup fields that follow (in the same or following FIXUPP records) may refer to that target or frame until another Thread field with the same type (target or frame) and thread number (0-3) appears (in the same or in another FIXUPP record).

Thread

The Thread field has the following format:



The TRD DAT (Thread Data) field is a byte with the following internal structure:



The D field is one bit and defines the type of thread being used. If D=0, this bit defines a target thread, and if D=1, it defines a frame thread.

Method is a 3-bit field containing a number between 0 and 3 (if D=0) or a number between 0 and 6 (if D=1).

If D=0, then Method = (0, 1, 2, 4, 5, 6)mod 4, where 0, 1, 2, 4, 5, 6 indicate methods T0, T1, T2, T4, T5, and T6 of specifying a target. Thus, Method indicates the kind of index or frame number required to specify the target, without indicating whether the target is specified by a primary or secondary method.

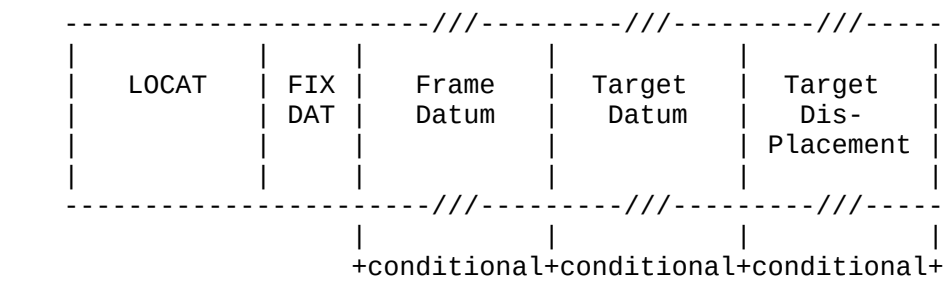
If D=1, then Method = 0, 1, 2, 4, 5, corresponding to methods F0, F1, F2, F4, F5 of specifying a frame. Here, Method indicates the kind (if any) of index required to specify the frame.

The THRED field contains a number between 0 and 3, inclusive, and associates a thread number to the frame or target defined by the Thread field.

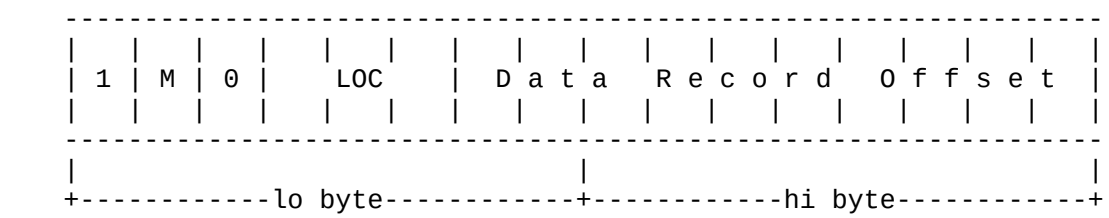
The Index field contains a segment index, group index, or external index depending on the specification in the Method field. If Method specifies F4 or F5, this field will not be present.

Fixup

The Fixup field has the following format:



The LOCAT field is a byte pair with the following format:



M is a 1-bit field that specifies the mode of the fixups: self-relative (if M=0) or segment-relative (if M=1).

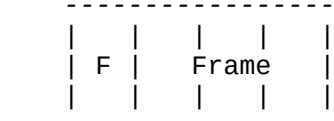
.....
Note
  Self-relative fixups may not be applied to LIDATA records.
.....

LOC is a 3-bit field indicating that the byte(s) in the preceding data record to be fixed up are a lobyte (if LOC=0), an offset (if LOC=1), a base (if LOC=2), a pointer (if LOC=3), a hibyte (if LOC=4), or a "loader-resolved" offset (if LOC=5). Any other values in LOC are invalid.

The Data Record Offset field contains a number between 0 and 1023, inclusive, that gives the relative position of the lowest order byte of Location (the actual bytes being fixed up) within the preceding data record. The Data Record Offset value is relative to the first byte in the data fields in the data records.

.....
Note
  If the preceding data record is an LIDATA record, it is possible for the Data Record Offset value to designate a location within a Repeat Count field or a Block Count field of the Iterated Data Block field. Such a reference is an error. The linker's action on such a malformed record is undefined.
.....

The FIX DAT field is a byte with the following format:



F is a 1-bit subfield that specifies whether the frame for this Fixup is specified by a thread (if F=1) or explicitly (if F=0).

The Frame field contains a number that is interpreted in one of two ways, as indicated by the F bit. If F is zero, the Frame field contains a number between 0 and 5, inclusive, corresponding to methods F0,...,F5 for specifying a frame. If F=1, then the Frame field contains a thread number (0-3). It specifies the frame most recently defined by a Thread field that defined a frame thread with the same thread number. (Note that the Thread field may appear in the same FIXUPP record, or in an earlier one.)

T is a 1-bit field that specifies whether the target specified for this fixup is defined by reference to a thread (T=1), or is given explicitly in the Fixup field (T=0).

P is a 1-bit field that indicates whether the Target is specified by a primary method (requires a target displacement, if P=0) or by a secondary method (requires no target displacement, if P=1). Since a target thread does not have a primary/secondary attribute, the P bit is the only field that contains the target specification attribute.

TARGT is interpreted as a 2-bit field. When T=0, it provides a number between 0 and 3, inclusive, corresponding to methods T0, T1, T2 or T4, T5, T6, depending on the value of P (where P is interpreted as the high-order bit of T0, T1, T2, T4, T5, or T6). When a thread specifies the target (if T=1), then the TARGET field specifies a thread number (0-3).

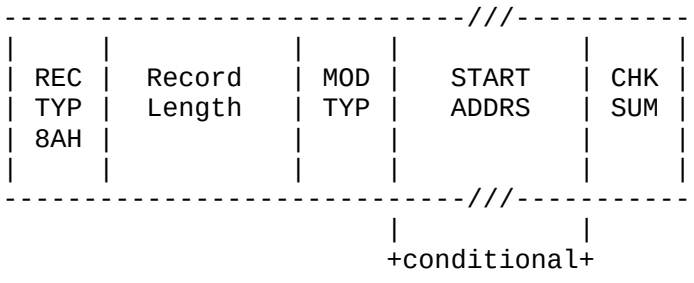
The Frame Datum field is the "referent" portion of a frame specification, and is a segment index, group index, or external index. The Frame Datum field is present only when the frame is not specified by a thread (if F=0) or explicitly by methods F4, F5, or F6.

The Target Datum field is the "referent" portion of a target specification, and is a segment index, group index, or external index. The Target Datum field is present only when a thread does not specify the target (if T=0).

The Target Displacement field is the 2-byte displacement required by primary methods of specifying targets. This field is present if P=0.

.....
Note
  All these methods are described in Section 7.3, "Conceptual Framework for Fixups."
.....

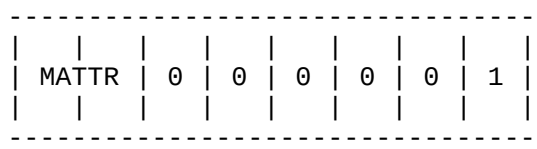
7.5.15 Module End Record (MODEND)



The MODEND record serves two purposes. It denotes the end of a module and indicates whether the module that just ended specifies an entry point to begin execution. If it does not, the linker specifies the execution address.

MOD TYP

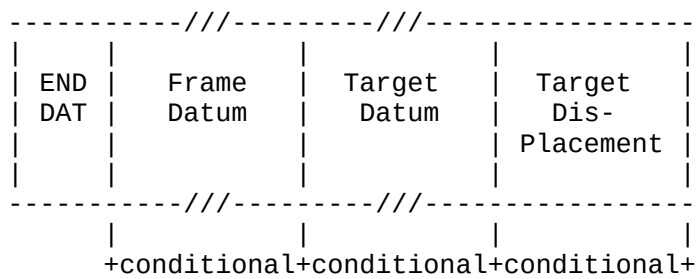
The MOD TYP field specifies the attributes of the module. The bit allocation and associated meanings are as follows:



MATTR is a 2-bit field that specifies the following module attributes:

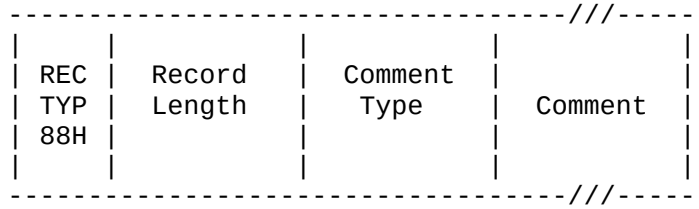
MATTR	Module Attribute
0	Non-main module with no START ADDRS
1	Non-main module with START ADDRS
2	Main module with no START ADDRS
3	Main module with START ADDRS

The START ADDRS field (present only if MATTR is 1 or 3) has the following format:



The starting address of a module has all the attributes of any other logical reference found in a module. The mapping of a logical starting address to a physical starting address is done in the same manner as mapping any other logical address to a physical address, as specified in the discussion of fixups and the FIXUPP record. The fields of the START ADDRS field have the same semantics as the FIX DAT, Frame Datum, Target Datum, and Target Displacement fields in the FIXUPP record. Only primary fixup methods are allowed. Frame method F4 is not allowed.

7.5.16 Comment Record (COMENT)



The COMENT record allows translators to include comments in object text.

Comment Type

The Comment Type field indicates the type of comment that this record carries, allowing you to structure comments for processes that selectively act on comments.

The format of the Comment Type field is as follows:

N P	N L	0	0	0	0	0	0	Comment Class

The NP (NOPURGE) bit, if set to 1, indicates that this comment cannot be purged by object file utility programs that can delete Comment records.

The NL (NOLIST) bit, if set to 1, indicates that the text in the Comment field should not appear in the listing file of object file utility programs that can list object Comment records.

The Comment Class field is a byte defined as follows:

Value	Meaning
Value	Meaning
0	Language Translator Comment (obsolete) If the comment field contains one of the strings "MS PASCAL" or "FORTRAN 77," then the comment record enables the dsallocation switch on the Microsoft linker.
156(9CH)	DOS Version The Comment field contains a 2-byte integer that specifies the DOS level number.
157(9DH)	Memory Model Indicates the memory model of the object module. The Comment field contains a single byte with the values S, M, L, or H, for SMALL, MEDIUM, LARGE, or HUGE, respectively. This Comment record is used only by the Microsoft XENIX linker.
Value	Meaning
#	only by the Microsoft XENIX linker.
158(9EH)	Force Segment Ordering Causes the linker to use a special segment ordering for executable files. This comment record has the same effect as giving the dosseg switch to Microsoft language versions of the linker.
159(9FH)	Library Specifier
129(81H)	Library Specifier (obsolete) Specifies a library to add to the Microsoft linker's library search list. The Comment field contains the name of the library. Note that unlike all other name specifications, the library name is not prefixed with its length but is determined by the record length. The nodefaultlibrarysearch switch causes the linker to ignore these comment records. The 159(9FH) class
Value	Meaning
#	to ignore these comment records. The 159(9FH) class record is ignored by XENIX versions of the

Microsoft linker.

161(A1H) Microsoft Extensions

Indicates that the object module contains extensions to the original Microsoft adaptation of the Intel Relocatable Object Module Format, such as the COMDEF and LOCSYM records.

Comment

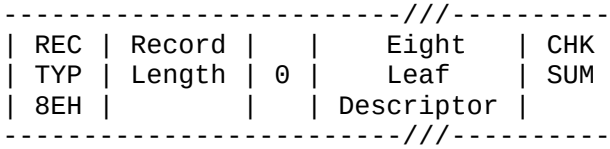
The Comment field provides the commentary information.

7.6 Microsoft Type Representations for Communal Variables

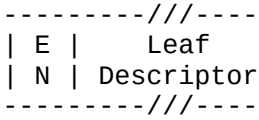
.....
Note
Object modules not containing the COMENT record from the Microsoft Extensions class can represent communal variable definitions only with the obsolete method described here. Also, Microsoft language linkers earlier than version 3.05 can recognize this method only. The newer method uses the Communal Variable Definitions (COMDEF) record.
.....

A communal variable is defined in the object text by an EXTDEF record and the TYPDEF record to which it refers.

The TYPDEF record of a communal variable has the following format:

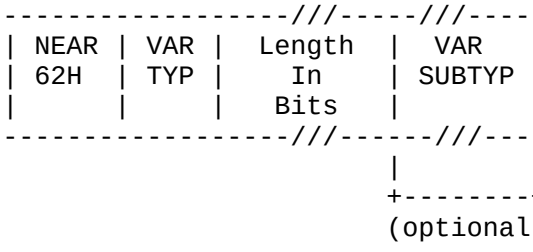


The Eight Leaf Descriptor field has the following format:



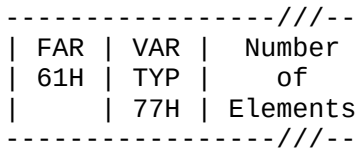
The EN bitfield specifies whether the next eight leaves in the Leaf Descriptor field are EASY (if EN = 0) or NICE (if EN = l). This byte is always zero for TYPDEFs of communal variables.

The Leaf Descriptor field has one of the following two formats. The format for communal variables in the default data segment (NEAR variables) is as follows:



The VARTYP (Variable Type) field may be either SCALAR (7BH), STRUCT

(79H), or ARRAY (77H). The linker ignores the VAR SUBTYP field (if one exists). The format for communal variables not in the default data segment (FAR variables) is as follows:



The VARTYP field must be ARRAY (77H). The Length in Bits field specifies the Number of Elements, and the Element Type Index is an index to a previously defined TYPDEF record whose format is that of a NEAR communal variable.

The format for the Length in Bits or Number of Elements fields is the same as the format of the Communal Length field of the COMDEF record.

Link-Time Semantics

All EXTDEF records referencing a TYPDEF record of one of the previously described formats are treated as communal variables. All others are treated as externally defined symbols for which a matching PUBDEF record is expected.

For more information, see "Link-Time Semantics" in Section 7.5.8, "Communal Names Definition Record (COMDEF)."

Chapter 8 Programming Hints

.....

8.1 Introduction

8.2 Interrupts

8.3 System Calls

8.4 Device Management

8.5 Memory Management

8.6 Process Management

8.7 File and Directory Management

8.7.1 Locking Files

8.8 Miscellaneous

8.1 Introduction

This chapter describes recommended MS-DOS 3.3 programming procedures. By using these programming hints, you can ensure compatibility with future versions of MS-DOS.

The hints are organized in the following categories:

·· Interrupts

·· System Calls

·· Device Management

·· Memory Management

·· Process Management

·· File and Directory Management

·· Miscellaneous

8.2 Interrupts

·· Never explicitly issue Interrupt 22H (Terminate Process Exit Address).

Only the DOS should do this. To change the terminate address, use Function 35H (Get Interrupt Vector) to get the current address and save it, then use Function 25H (Set Interrupt Vector) to change the Interrupt 22H entry in the vector table to point to the new terminate address.

·· Use Interrupt 24H (Critical-Error-Handler Address) with care. The Interrupt 24H handler must preserve the ES register.

An Interrupt 24H handler can issue only the system calls 01H-0CH. Making any other calls destroys the MS-DOS stack and prevents successful use of the Retry or Ignore options.

When using the Retry or Ignore options, you must preserve the SS, SP, DS, BX, CX, and DX registers.

·· When an Interrupt 24H (Critical-Error-Handler Address) is received, always IRET back to MS-DOS with one of the standard responses.

Programs that do not IRET from Interrupt 24H leave the system in an unpredictable state until a function call other than 01H-0CH is made. The Ignore option may leave incorrect or invalid data in internal system buffers.

·· Avoid trapping Interrupt 23H (CONTROL-C Handler Address) and Interrupt 24H (Critical-Error-Handler Address). Don't rely on trapping errors via Interrupt 24H as part of a copy protection scheme.

These methods might not be included in future releases of MS-DOS.

·· A user program must never issue Interrupt 23H (CONTROL-C Handler Address).

Only MS-DOS may issue Interrupt 23H.

·· Save any registers that your program uses before issuing Interrupt 25H (Absolute Disk Read) or Interrupt 26H (Absolute Disk Write).

These interrupts destroy all registers except for the segment registers.

Avoid writing or reading an interrupt vector directly to or

from memory.

·· Use Functions 25H and 35H (Set Interrupt Vector and Get Interrupt Vector) to set and get values in the interrupt table.

8.3 System Calls

·· Use new system calls.

Avoid using system calls that have been superseded by new calls unless the program must maintain backward compatibility with MS-DOS versions before 2.0. See Section 1.9, "Old System Calls", for a list of these new calls.

·· Avoid using functions 01H-0CH and 26H (Create New PSP).

Use the new "tools" approach for reading and writing on standard input and output. Use Function 4BH (Load and Execute Program) instead of 26H to execute a child process.

·· Use file-sharing calls if more than one process is in effect.

For more information, see File Sharing, in Section 1.5.2, "File-Related Function Requests."

·· Use networking calls where appropriate.

Some forms of IOCtl can only be used with Microsoft Networks. For more information, and a list of these calls, see Section 1.6, "Microsoft Networks,"

·· When selecting a disk with Function 0EH (Select Disk), treat the value returned in AL with care.

The value in AL specifies the maximum number of logical drives; it does not specify which drives are valid.

8.4 Device Management

·· Use installable device drivers.

MS-DOS provides a modular device driver structure for the BIOS, allowing you to configure and install device drivers at boot time. Block device drivers transmit a block of data at a time, while character device drivers transmit a byte of data at a time.

Examples of both types of device drivers are given in Chapter 2, "MS-DOS Device Drivers."

·· Use buffered I/O.

The device drivers can handle streams of data up to 64K bytes. To improve performance when sending a large amount of output to the screen, you can send it with one system call.

·· Programs that use direct console I/O via Function 06H and 07H (Direct Console I/O and Direct Console Input) and that want to read CONTROL-C as data should ensure that CONTROL-C checking is off.

The program should ensure that CONTROL-C checking is off by using Function 33H (CONTROL-C Check).

·· Be compatible with international support.

To provide support for international character sets, MS-DOS recognizes all possible byte values as significant characters in filenames and data streams. MS-DOS versions before 2.0 ignored the high bit in the MS-DOS filename.

8.5 Memory Management

·· Use memory management.

MS-DOS keeps track of allocated memory by writing a memory control block at the beginning of each area of memory. Programs should use Functions 48H (Allocate Memory), 49H (Free Allocated Memory), and 4AH (Set Block) to release unneeded memory.

This allows for future compatibility. For more information, see Section 1.3, "Memory Management."

·· Use only allocated memory.

Don't directly access memory that was not provided as a result of a system call. Do not use fixed addressing, use only relative references.

A program that uses memory that has not been allocated to it may destroy other memory control blocks or cause other applications to fail.

8.6 Process Management

·· Use Function 4BH (Load and Execute Program, or EXEC) to load and execute programs.

EXEC is the preferred call to use when loading programs and program overlays. Using the EXEC call instead of hard-coding information about how to load an .exe file (or always assuming that your file is a .com file) isolates your program from changes in .exe file formats and future releases of MS-DOS.

·· Use Function 31H (Keep Process), instead of Interrupt 27H (Terminate But Stay Resident).

Function 31H allows programs that are greater than 64K bytes to terminate and stay resident.

·· Programs should terminate using Function 4CH (End Process).

Programs that terminate by one of the following must ensure that the CS register contains the segment address of the PSP:

·· A long jump to offset 0 in the PSP

·· Issuing an Interrupt 20H with CS:0 pointing at the PSP

·· Issuing an Interrupt 21H with AH=0, CS:0 pointing at the PSP

·· A long call to location 50H in the PSP with AH=0

8.7 File and Directory Management

·· Use the MS-DOS file management system.

Using the MS-DOS file system ensures program compatibility with future MS-DOS versions through compatible disk formats and consistent internal storage.

·· Use file handles instead of FCBs.

A handle is a 16-bit number that MS-DOS returns when a file is opened or created using Functions 3CH, 3DH, 5AH, or 5BH (Create Handle, Open Handle, Create Temporary File, or Create New File). The MS-DOS file-related function requests that use handles are listed in Table 1.5 in Chapter 1, "System Calls."

Although the default maximum number of open files is 20, this limit can be raised to 64K by Function 67H (Set Handle Count). For more information on this system call, see Chapter 1, "System Calls."

You should use these calls instead of the old file-related functions that use FCBs (file control blocks). This is because a file operation can simply pass its handle rather than maintaining FCB information. If you must use FCBs, be sure the program closes them and does not move them around in memory.

·· Close files that have changed in length before issuing an Interrupt 20H (Program Terminate), Function 00H (Terminate Program), Function 4CH (End Process), or Function 0DH (Reset Disk).

If you do not close a changed file, its length will not be recorded correctly in the directory.

·· Close files when they are no longer needed.

Closing unneeded files increases efficiency in a networking environment.

·· If a program does use FCBs, that program should not close an FCB file and then continue writing to it. This practice will not work in a network environment, and is not recommended under any circumstances.

·· Change disks only if all files on the disk are closed.

If you don't close all the files, any information in internal system buffers may be written incorrectly to a changed disk.

8.7.1 Locking Files

·· Programs should not rely on being denied access to a locked region.

To determine the status of a region, first, attempt to lock it, then examine its error code.

·· Programs should not close a file with a locked region or terminate with an open file that contains a locked region.

The result of this procedure is undefined. Programs that might be terminated by an Interrupt 23H or Interrupt 24H (CONTROL-C Handler Address or Critical-Error-Handler Address) should trap these interrupts and unlock any locked regions before exiting.

8.8 Miscellaneous

·· Avoid timing dependencies.

Various machines use CPUs of different speeds. Also, programs that rely upon the speed of the clock for timing are not dependable in a networking environment.

·· Use the documented interface to the operating system. If either the hardware or media change, the operating system can use the features without modification.

Don't use the ROM support provided by the OEM (Original Equipment Manufacturer).

Don't directly address the video memory.

Don't use undocumented function calls, interrupts, or features.

These items may change or may not exist in future MS-DOS versions. If you do use these features, you will make your program highly non-portable.

·· Use the .exe format rather than the .com format.

.Exe files are relocatable; .com files are direct memory images that load at a specific place and have no room for additional control information. .Exe files have headers that can be expanded for compatibility with future MS-DOS versions.

·· Use the environment to pass information to applications.

The environment allows a parent process to pass information to a child process. The command.com file is usually the parent process to every application, so it can easily pass default drive and path information to the application.

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